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## PROVISIONAL APPLICATION FOR PATENT COVER SHEET

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INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
SHAWN	DEFREES	North Wales, PA
<input type="checkbox"/> Additional inventors are being named on the separately numbered sheets attached hereto		
TITLE OF THE INVENTION (500 characters max)		
SUGAR CONJUGATES		
Direct all correspondence to: CORRESPONDENCE ADDRESS		
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[Page 1 of 2]

Respectfully submitted,

SIGNATURE

Date July 29, 2004TYPED or PRINTED NAME Jeffry S. MannREGISTRATION NO. 42,837

(if appropriate)

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**PROVISIONAL**

**PATENT APPLICATION**

**SUGAR CONJUGATES**

Inventor(s): Shawn DeFrees, a citizen of the United States, residing at  
126 Filly Drive  
North Wales, PA 19454

Assignee: Neose Technologies, Inc.  
102 Witmer Road  
Horsham, PA, 19044

Entity: Small

Jeffry S. Mann, Ph.D.  
Reg. No. 42,837

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MORGAN  
LEWIS AND  
BOCKIUS  
LLP

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**Correspondence Address:**

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One Market  
Spear Street Tower  
San Francisco  
California 94105  
Tel 415 442-1119  
Fax 415 442-1000

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## SUGAR CONJUGATES

### BACKGROUND OF THE INVENTION

#### Field of the Invention

5 [0001] The present invention relates to activated modified sugar conjugates and therapeutic peptides and glycopeptides that are enzymatically derivatized using these conjugates.

#### Background

[0002] The administration of glycosylated and non-glycosylated peptides for engendering a particular physiological response is well known in the medicinal arts. For example, both 10 purified and recombinant hGH are used for treating conditions and diseases due to hGH deficiency, *e.g.*, dwarfism in children, interferon has known antiviral activity and granulocyte colony stimulating factor stimulates the production of white blood cells.

[0003] A principal factor that has limited the use of therapeutic peptides is the difficulty inherent in engineering an expression system to express a peptide having the glycosylation 15 pattern of the wild-type peptide. Improperly or incompletely glycosylated peptides can be immunogenic; in a patient, an immunogenic response to an administered peptide can neutralize the peptide and/or lead to the development of an allergic response in the patient. Other deficiencies of recombinantly produced glycopeptides include suboptimal potency and 20 rapid clearance rates. The problems inherent in peptide therapeutics are recognized in the art, and various methods of eliminating the problems have been investigated.

[0004] Post-expression *in vitro* modification of peptides is an attractive strategy to remedy the deficiencies of methods that rely on controlling glycosylation by engineering expression systems; including both modification of glycan structures or introduction of glycans at novel sites. A comprehensive toolbox of recombinant eukaryotic glycosyltransferases is becoming 25 available, making *in vitro* enzymatic synthesis of mammalian glycoconjugates with custom designed glycosylation patterns and glycosyl structures possible. See, for example, U.S. Patent No. 5,876,980; 6,030,815; 5,728,554; 5,922,577; and WO/9831826; US2003180835; and WO 03/031464.

[0005] Enzyme-based syntheses have the advantages of regioselectivity and 30 stereoselectivity. Moreover, enzymatic syntheses are performed using unprotected substrates. Three principal classes of enzymes are used in the synthesis of carbohydrates,

glycosyltransferases (e.g., sialyltransferases, oligosaccharyltransferases, N-acetylglucosaminyltransferases), and glycosidases. The glycosidases are further classified as exoglycosidases (e.g.,  $\beta$ -mannosidase,  $\beta$ -glucosidase), and endoglycosidases (e.g., Endo-A, Endo-M). Each of these classes of enzymes has been successfully used synthetically to 5 prepare carbohydrates. For a general review, see, Crout *et al.*, *Curr. Opin. Chem. Biol.* **2**: 98-111 (1998).

[0006] Glycosyltransferases modify the oligosaccharide structures on glycopeptides. Glycosyltransferases are effective for producing specific products with good stereochemical and regiochemical control. Glycosyltransferases have been used to prepare oligosaccharides 10 and to modify terminal N- and O-linked carbohydrate structures, particularly on glycopeptides produced in mammalian cells. For example, the terminal oligosaccharides of glycopeptides have been completely sialylated and/or fucosylated to provide more consistent sugar structures, which improves glycopeptide pharmacodynamics and a variety of other biological properties. For example,  $\beta$ -1,4-galactosyltransferase was used to synthesize 15 lactosamine, an illustration of the utility of glycosyltransferases in the synthesis of carbohydrates (see, e.g., Wong *et al.*, *J. Org. Chem.* **47**: 5416-5418 (1982)). Moreover, numerous synthetic procedures have made use of  $\alpha$ -sialyltransferases to transfer sialic acid 20 from cytidine-5'-monophospho-N-acetylneurameric acid to the 3-OH or 6-OH of galactose (see, e.g., Kevin *et al.*, *Chem. Eur. J.* **2**: 1359-1362 (1996)). Fucosyltransferases are used in synthetic pathways to transfer a fucose unit from guanosine-5'-diphosphofucose to a specific 25 hydroxyl of a saccharide acceptor. For example, Ichikawa prepared sialyl Lewis-X by a method that involves the fucosylation of sialylated lactosamine with a cloned fucosyltransferase (Ichikawa *et al.*, *J. Am. Chem. Soc.* **114**: 9283-9298 (1992)). For a discussion of recent advances in glycoconjugate synthesis for therapeutic use see, Koeller *et* 30 *al.*, *Nature Biotechnology* **18**: 835-841 (2000). See also, U.S. Patent No. 5,876,980; 6,030,815; 5,728,554; 5,922,577; and WO/9831826.

[0007] Glycosidases can also be used to prepare saccharides. Glycosidases normally catalyze the hydrolysis of a glycosidic bond. Under appropriate conditions, however, they can be used to form this linkage. Most glycosidases used for carbohydrate synthesis are 30 exoglycosidases; the glycosyl transfer occurs at the non-reducing terminus of the substrate. The glycosidase takes up a glycosyl donor in a glycosyl-enzyme intermediate that is either intercepted by water to give the hydrolysis product, or by an acceptor, to give a new glycoside or oligosaccharide. An exemplary pathway using an exoglycosidase is the

synthesis of the core trisaccharide of all N-linked glycopeptides, including the difficult  $\beta$ -mannoside linkage, which was formed by the action of  $\beta$ -mannosidase (Singh *et al.*, *Chem. Commun.* 993-994 (1996)).

[0008] In another exemplary application of the use of a glycosidase to form a glycosidic linkage, a mutant glycosidase was prepared in which the normal nucleophilic amino acid within the active site is changed to a non-nucleophilic amino acid. The mutant enzymes do not hydrolyze glycosidic linkages, but can still form them. The mutant glycosidases are used to prepare oligosaccharides using an  $\alpha$ -glycosyl fluoride donor and a glycoside acceptor molecule (Withers *et al.*, U.S. Patent No. 5,716,812). Although the mutant glycosidases are useful for forming free oligosaccharides, it has yet to be demonstrated that such enzymes are capable of appending glycosyl donors onto glycosylated or non-glycosylated peptides, nor have these enzymes been used with unactivated glycosyl donors.

[0009] Although their use is less common than that of the exoglycosidases, endoglycosidases are also utilized to prepare carbohydrates. Methods based on the use of endoglycosidases have the advantage that an oligosaccharide, rather than a monosaccharide, is transferred. Oligosaccharide fragments have been added to substrates using *endo*- $\beta$ -N-acetylglucosamines such as *endo*-F, *endo*-M (Wang *et al.*, *Tetrahedron Lett.* 37: 1975-1978); and Haneda *et al.*, *Carbohydr. Res.* 292: 61-70 (1996)).

[0010] In addition to their use in preparing carbohydrates, the enzymes discussed above are applied to the synthesis of glycopeptides. The synthesis of a homogenous glycoform of ribonuclease B has been published (Witte K. *et al.*, *J. Am. Chem. Soc.* 119: 2114-2118 (1997)). The high mannose core of ribonuclease B was cleaved by treating the glycopeptide with endoglycosidase H. The cleavage occurred specifically between the two core GlcNAc residues. The tetrasaccharide sialyl Lewis X was then enzymatically rebuilt on the remaining GlcNAc anchor site on the now homogenous protein by the sequential use of  $\beta$ -1,4-galactosyltransferase,  $\alpha$ -2,3-sialyltransferase and  $\alpha$ -1,3-fucosyltransferase V. Each enzymatically catalyzed step proceeded in excellent yield.

[0011] Methods combining both chemical and enzymatic synthetic elements are also known. For example, Yamamoto and coworkers (*Carbohydr. Res.* 305: 415-422 (1998)) reported the chemoenzymatic synthesis of the glycopeptide, glycosylated Peptide T, using an endoglycosidase. The N-acetylglucosaminyl peptide was synthesized by purely chemical means. The peptide was subsequently enzymatically elaborated with the oligosaccharide of

human transferrin glycopeptide. The saccharide portion was added to the peptide by treating it with an endo- $\beta$ -N-acetylglucosaminidase. The resulting glycosylated peptide was highly stable and resistant to proteolysis when compared to the peptide T and N-acetylglucosaminyl peptide T.

5 [0012] The use of glycosyltransferases to modify peptide structure with reporter groups has been explored. For example, Grossmer *et al.* (U.S. Patent No. 5,405,753) discloses the formation of a fluorescent-labeled cytidine monophosphate ("CMP") derivative of sialic acid and the use of the fluorescent glycoside in an assay for sialyl transferase activity and for the fluorescent labeling of cell surfaces, glycoproteins and gangliosides. Gross *et al.* (*Analyt.* 10 *Biochem.* 186: 127 (1990)) describe a similar assay. Bean *et al.* (U.S. Patent No. 5,432,059) discloses an assay for glycosylation deficiency disorders utilizing reglycosylation of a deficiently glycosylated protein. The deficient protein is reglycosylated with a fluorescent-labeled CMP glycoside. Each of the fluorescent sialic acid derivatives is substituted with the fluorescent moiety at either the 9-position or at the amine that is normally acetylated in sialic 15 acid. The methods using the fluorescent sialic acid derivatives are assays for the presence of glycosyltransferases or for non-glycosylated or improperly glycosylated glycoproteins. The assays are conducted on small amounts of enzyme or glycoprotein in a sample of biological origin. The enzymatic derivatization of a glycosylated or non-glycosylated peptide on a preparative or industrial scale using a modified sialic acid has not been disclosed or 20 suggested.

25 [0013] Considerable effort has also been directed towards the modification of cell surfaces by altering glycosyl residues presented by those surfaces. For example, Fukuda and coworkers have developed a method for attaching glycosides of defined structure onto cell surfaces. The method exploits the relaxed substrate specificity of a fucosyltransferase that can transfer fucose and fucose analogs bearing diverse glycosyl substrates (Tsuboi *et al.*, *J. Biol. Chem.* 271: 27213 (1996)).

30 [0014] The methods of modifying cell surfaces have not been applied in the absence of a cell to modify a glycosylated or non-glycosylated peptide. Moreover, the methods of cell surface modification are not utilized for the enzymatic incorporation preformed modified glycosyl donor moiety into a peptide. Moreover, none of the cell surface modification methods are practical for producing glycosyl-modified peptides on an industrial scale.

[0015] Enzymatic methods have also been used to activate glycosyl residues on a glycopeptide towards subsequent chemical elaboration. The glycosyl residues are typically activated using galactose oxidase, which converts a terminal galactose residue to the corresponding aldehyde. The aldehyde is subsequently coupled to an amine-containing 5 modifying group. For example, Casares *et al.* (*Nature Biotech.* **19**: 142 (2001)) have attached doxorubicin to the oxidized galactose residues of a recombinant MHCII-peptide chimera.

[0016] In addition to manipulating the structure of glycosyl groups on polypeptides, interest has developed in preparing glycopeptides that are modified with one or more non-saccharide modifying group, such as water soluble polymers. Poly(ethyleneglycol) (“PEG”) 10 is an exemplary polymer that has been conjugated to polypeptides. The use of PEG to derivatize peptide therapeutics has been demonstrated to reduce the immunogenicity of the peptides. For example, U.S. Pat. No. 4,179,337 (Davis *et al.*) discloses non-immunogenic polypeptides, such as enzymes and peptide hormones coupled to polyethylene glycol (PEG) or polypropylene glycol. Between 10 and 100 moles of polymer are used per mole 15 polypeptide. Although the *in vivo* clearance time of the conjugate is prolonged relative to that of the polypeptide, only about 15% of the physiological activity is maintained. Thus, the prolonged circulation half-life is counterbalanced by the dramatic reduction in peptide potency.

[0017] The loss of peptide activity is directly attributable to the non-selective nature of the 20 chemistries utilized to conjugate the water-soluble polymer. The principal mode of attachment of PEG, and its derivatives, to peptides is a non-specific bonding through a peptide amino acid residue. For example, U.S. Patent No. 4,088,538 discloses an enzymatically active polymer-enzyme conjugate of an enzyme covalently bound to PEG. Similarly, U.S. Patent No. 4,496,689 discloses a covalently attached complex of  $\alpha$ -1 25 proteinase inhibitor with a polymer such as PEG or methoxypoly(ethyleneglycol) (“(m-) PEG”). Abuchowski *et al.* (*J. Biol. Chem.* **252**: 3578 (1977)) discloses the covalent attachment of (m-) PEG to an amine group of bovine serum albumin. U.S. Patent No. 4,414,147 discloses a method of rendering interferon less hydrophobic by conjugating it to an 30 anhydride of a dicarboxylic acid, such as poly(ethylene succinic anhydride). PCT WO 87/00056 discloses conjugation of PEG and poly(oxyethylated) polyols to such proteins as interferon- $\beta$ , interleukin-2 and immunotoxins. EP 154,316 discloses and claims chemically modified lymphokines, such as IL-2 containing PEG bonded directly to at least one primary amino group of the lymphokine. U.S. Patent No. 4,055,635 discloses pharmaceutical

compositions of a water-soluble complex of a proteolytic enzyme linked covalently to a polymeric substance such as a polysaccharide.

[0018] Another mode of attaching PEG to peptides is through the non-specific oxidation of glycosyl residues on a glycopeptide. The oxidized sugar is utilized as a locus for attaching a PEG moiety to the peptide. For example M'Timkulu (WO 94/05332) discloses the use of an amino-PEG to add PEG to a glycoprotein. The glycosyl moieties are randomly oxidized to the corresponding aldehydes, which are subsequently coupled to the amino-PEG.

[0019] In each of the methods described above, poly(ethyleneglycol) is added in a random, non-specific manner to reactive residues on a peptide backbone. For the production of therapeutic peptides, it is clearly desirable to utilize a derivitization strategy that results in the formation of a specifically labeled, readily characterizable, essentially homogeneous product. A promising route to preparing specifically labeled peptides is through the use of enzymes, such as glycosyltransferases to append a modified sugar moiety onto a peptide.

[0020] Glycosyl residues have also been modified to bear ketone groups. For example, Mahal and co-workers (*Science* **276**: 1125 (1997)) have prepared N-levulinoyl mannosamine (“ManLev”), which has a ketone functionality at the position normally occupied by the acetyl group in the natural substrate. Cells were treated with the ManLev, thereby incorporating a ketone group onto the cell surface. *See, also* Saxon *et al.*, *Science* **287**: 2007 (2000); Hang *et al.*, *J. Am. Chem. Soc.* **123**: 1242 (2001); Yarema *et al.*, *J. Biol. Chem.* **273**: 31168 (1998); and Charter *et al.*, *Glycobiology* **10**: 1049 (2000).

[0021] In addition to an industrially relevant method that utilizes the enzymatic conjugation to specifically conjugate a modified sugar to a peptide or glycopeptide, a method for controlling and manipulating the position of glycosylation on a glycopeptide would be highly desirable.

[0022] Carbohydrates are attached to glycopeptides in several ways of which N-linked to asparagine and mucin-type O-linked to serine and threonine are the most relevant for recombinant glycoprotein therapeutics. A determining factor for initiation of glycosylation of a protein is the primary sequence context, although clearly other factors including protein region and conformation play roles. N-linked glycosylation occurs at the consensus sequence NXS/T, where X can be any amino acid but proline.

[0023] O-linked glycosylation is initiated by a family of about 20 homologous enzymes termed UDP-GalNAc: polypeptide *N*-acetylgalactosaminyltransferases (GalNAc-transferases). O-linked glycosylation does not appear to be ruled by one simple consensus sequence, although studies of the GalNAc-transferase enzymes that initiate O-linked glycosylation clearly supports the notion that their acceptor specificities are driven by primary sequence contexts. Each of these enzymes transfer a single monosaccharide GalNAc to serine and threonine residues, but they transfer to different peptide sequences although they show a large degree of overlap in functions. It is envisioned that the substrate specificity of each GalNAc-transferase is ruled primarily by a linear short acceptor consensus sequence.

[0024] The present invention answers the need for modified sugars that are readily conjugated onto N- or O-linked glycosylation sites of peptides and other bioactive species, e.g., glycolipids, sphingosines, ceramides, etc. The activated modified sugars of the invention afford access to N- and O-linked site selective formation of conjugates of peptides and glycopeptides, opening a route to new therapeutic peptide conjugates and addressing the need for more stable and therapeutically effective therapeutic peptides. Moreover, despite the efforts directed toward the enzymatic elaboration of saccharide structures, there remains still a need for an industrially practical method for the modification of peptides and glycopeptides with modifying groups such as water-soluble polymers, therapeutic moieties, biomolecules and the like. Of particular interest are methods in which the modified peptide has improved properties, which enhance its use as a therapeutic or diagnostic agent. The present invention fulfills these and other needs.

#### BRIEF SUMMARY OF THE INVENTION

[0025] The present invention provides conjugates of N-acetyl saccharides that are functionalized with a modifying group through an amine-derived linking group at C-6 of the saccharide. Also provided are activated derivatives of the saccharides, such as nucleotide sugars. The activated derivatives are of use in the enzymatically-mediated formation of conjugates between the modifying group and an amino acid or glycosyl residue of a peptide, glycolipid or aglycone (e.g., ceramide and sphingosine).

[0026] In an exemplary embodiment, the invention provides a saccharide conjugate that includes a saccharyl core that is derivatized with a N-acyl moiety. The core is also functionalized with a -NHR-(CH<sub>2</sub>CH<sub>2</sub>O)<sub>n</sub>CH<sub>2</sub>CH<sub>2</sub>OR<sup>1</sup> moiety, typically at C-6. The symbol

R represents C(O)(CH<sub>2</sub>)<sub>m</sub>O, C(O)NH(CH<sub>2</sub>)<sub>m</sub>O, or C(O)O(CH<sub>2</sub>)<sub>m</sub>O. The index m is an integer from 0 to 20. R<sup>1</sup> is a member selected from H, substituted or unsubstituted alkyl (e.g., alkylaryl), substituted or unsubstituted aryl; and n is an integer from 1 to 2500. Also provided are activated saccharide conjugates that function as glycosyl donors in an enzymatically-mediated glycosylation reaction.

5 [0027] Glycotherapeutics, e.g., glycopeptides present a challenging target for recombinant production of therapeutics. For example, carbohydrates are often indispensable for the function and favorable pharmacokinetic properties of glycopeptide therapeutics. Accordingly, considerable efforts are expended to develop recombinant expression cell 10 systems capable of producing glycoproteins with biologically appropriate carbohydrate structures. This approach is hampered by numerous shortcomings, including cost, and heterogeneity and limitations in glycan structures.

15 [0028] Post-expression *in vitro* glyco-modification of glycotherapeutics, e.g., glycopeptides, is an attractive strategy to remedy the deficiencies of methods that rely on controlling glycosylation by engineering expression systems; including both modification of glycan structures or introduction of glycans at novel sites. A comprehensive toolbox of recombinant eukaryotic glycosyltransferases is becoming available, making *in vitro* enzymatic synthesis of mammalian glycoconjugates with custom designed glycosylation patterns and glycosyl structures possible. See, for example, U.S. Patent No. 5,876,980; 20 6,030,815; 5,728,554; 5,922,577; and WO/9831826; US2003180835; and WO 03/031464.

25 [0029] *In vitro* glycosylation offers a number of advantages compared to recombinant expression of glycoproteins of which custom design and higher degree of homogeneity of the glycosyl moiety are examples. Moreover, combining bacterial expression of glycotherapeutics with *in vitro* modification (or placement) of the glycosyl residue offers numerous advantages over traditional recombinant expression technology including reduced potential exposure to adventitious agents, increased homogeneity of product, and cost reduction.

30 [0030] In addition to activated modified sugars of use in forming glycoconjugates, the invention provides methods of improving pharmacological parameters of glycotherapeutics. For example, the invention provides a means for altering the pharmacokinetics, pharmacodynamics and bioavailability of therapeutic (glyco)peptides, e.g., cytokines, antibodies, growth hormones, and enzymes; and glycolipids. In particular, the invention

provides a method for lengthening the *in vivo* half-lives of a glycotherapeutic by conjugating a water-soluble polymer to the therapeutic moiety through a glycosyl linking group, e.g., an intact glycosyl linking group. In an exemplary embodiment, covalent attachment of polymers, such as polyethylene glycol (PEG), e.g., m-PEG, to a therapeutic moiety affords 5 conjugates having *in vivo* residence times, and pharmacokinetic and pharmacodynamic properties, enhanced relative to the unconjugated therapeutic.

[0031] As discussed in the preceding section, art-recognized methods of covalent PEGylation rely on chemical conjugation through reactive groups, typically amines, on amino acids or carbohydrates. A major shortcoming of chemical conjugation of PEG to 10 proteins or glycoproteins is lack of selectivity, which often results in attachment of PEG at sites implicated in protein or glycoprotein bioactivity. Several strategies have been developed to address site selective conjugation chemistries, however, one universal method suitable for a variety of recombinant proteins has yet to be developed.

[0032] In contrast to art-recognized methods, the present invention provides a novel 15 strategy for highly selective site directed glycoconjugation, e.g., glyco-PEGylation. In an exemplary embodiment of the invention, site directed attachment sites for PEGylation are provided by *in vitro* enzymatic glycosylation of specific peptide sequences with the modified activated sugars of the invention.

[0033] Also provided is a peptide conjugate that is formed using an activated saccharide of 20 the invention. An exemplary peptide conjugate includes the modifying group attached to an amino acid, or glycosyl residue, of the peptide through a glycosyl linking group, e.g., an intact glycosyl linking group.

[0034] Additional aspects, advantages and objects of the present invention will be apparent 25 from the detailed description that follows.

## DETAILED DESCRIPTION OF THE INVENTION

### Abbreviations

[0035] PEG, poly(ethyleneglycol); m-PEG, methoxy-poly(ethylene glycol); PPG, 30 poly(propyleneglycol); m-PPG, methoxy-poly(propylene glycol); Fuc, fucosyl; Gal, galactosyl; GalNAc, N-acetylgalactosaminyl; Glc, glucosyl; GlcNAc, N-acetylglucosaminyl; Man, mannosyl; ManAc, mannosaminyl acetate; Sia, sialic acid; and NeuAc, N-acetylneuraminy.

## Definitions

[0036] Unless defined otherwise, all technical and scientific terms used herein generally have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Generally, the nomenclature used herein and the laboratory

5 procedures in cell culture, molecular genetics, organic chemistry and nucleic acid chemistry and hybridization are those well known and commonly employed in the art. Standard techniques are used for nucleic acid and peptide synthesis. The techniques and procedures are generally performed according to conventional methods in the art and various general references (*see generally*, Sambrook *et al.* MOLECULAR CLONING: A LABORATORY MANUAL, 10 2d ed. (1989) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., which is incorporated herein by reference), which are provided throughout this document. The nomenclature used herein and the laboratory procedures in analytical chemistry, and organic synthetic described below are those well known and commonly employed in the art. Standard techniques, or modifications thereof, are used for chemical syntheses and chemical 15 analyses.

[0037] The term "alkyl," by itself or as part of another substituent, means, unless otherwise stated, a straight or branched chain, or cyclic hydrocarbon radical, or combination thereof, which may be fully saturated, mono- or polyunsaturated and can include di- and multivalent radicals, having the number of carbon atoms designated (*i.e.* C<sub>1</sub>-C<sub>10</sub> means one to ten

20 carbons). Examples of saturated hydrocarbon radicals include, but are not limited to, groups such as methyl, ethyl, n-propyl, isopropyl, n-butyl, t-butyl, isobutyl, sec-butyl, cyclohexyl, (cyclohexyl)methyl, cyclopropylmethyl, homologs and isomers of, for example, n-pentyl, n-hexyl, n-heptyl, n-octyl, and the like. An unsaturated alkyl group is one having one or more double bonds or triple bonds. Examples of unsaturated alkyl groups include, but are not 25 limited to, vinyl, 2-propenyl, crotyl, 2-isopentenyl, 2-(butadienyl), 2,4-pentadienyl, 3-(1,4-pentadienyl), ethynyl, 1- and 3-propynyl, 3-butynyl, and the higher homologs and isomers. The term "alkyl," unless otherwise noted, is also meant to include those derivatives of alkyl defined in more detail below, such as "heteroalkyl." Alkyl groups, which are limited to hydrocarbon groups are termed "homoalkyl".

30 [0038] The term "alkylene" by itself or as part of another substituent means a divalent radical derived from an alkane, as exemplified, but not limited, by -CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>-, and further includes those groups described below as "heteroalkylene." Typically, an alkyl (or alkylene) group will have from 1 to 24 carbon atoms, with those groups having 10 or fewer

carbon atoms being preferred in the present invention. A “lower alkyl” or “lower alkylene” is a shorter chain alkyl or alkylene group, generally having eight or fewer carbon atoms.

[0039] The terms “alkoxy,” “alkylamino” and “alkylthio” (or thioalkoxy) are used in their conventional sense, and refer to those alkyl groups attached to the remainder of the molecule 5 via an oxygen atom, an amino group, or a sulfur atom, respectively.

[0040] The term “heteroalkyl,” by itself or in combination with another term, means, unless otherwise stated, a stable straight or branched chain, or cyclic hydrocarbon radical, or combinations thereof, consisting of the stated number of carbon atoms and at least one heteroatom selected from the group consisting of O, N, Si and S, and wherein the nitrogen 10 and sulfur atoms may optionally be oxidized and the nitrogen heteroatom may optionally be quaternized. The heteroatom(s) O, N and S and Si may be placed at any interior position of the heteroalkyl group or at the position at which the alkyl group is attached to the remainder of the molecule. Examples include, but are not limited to, -CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>3</sub>, -CH<sub>2</sub>-CH<sub>2</sub>-NH-CH<sub>3</sub>, -CH<sub>2</sub>-CH<sub>2</sub>-N(CH<sub>3</sub>)-CH<sub>3</sub>, -CH<sub>2</sub>-S-CH<sub>2</sub>-CH<sub>3</sub>, -CH<sub>2</sub>-CH<sub>2</sub>-S(O)-CH<sub>3</sub>, -CH<sub>2</sub>-CH<sub>2</sub>-S(O)<sub>2</sub>- 15 CH<sub>3</sub>, -CH=CH-O-CH<sub>3</sub>, -Si(CH<sub>3</sub>)<sub>3</sub>, -CH<sub>2</sub>-CH=N-OCH<sub>3</sub>, and -CH=CH-N(CH<sub>3</sub>)-CH<sub>3</sub>. Up to two heteroatoms may be consecutive, such as, for example, -CH<sub>2</sub>-NH-OCH<sub>3</sub> and -CH<sub>2</sub>-O-Si(CH<sub>3</sub>)<sub>3</sub>. Similarly, the term “heteroalkylene” by itself or as part of another substituent means a divalent radical derived from heteroalkyl, as exemplified, but not limited by, -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>2</sub>-CH<sub>2</sub>- and -CH<sub>2</sub>-S-CH<sub>2</sub>-CH<sub>2</sub>-NH-CH<sub>2</sub>- For heteroalkylene groups, heteroatoms 20 can also occupy either or both of the chain termini (e.g., alkyleneoxy, alkylenedioxy, alkyleneamino, alkylenediamino, and the like). Still further, for alkylene and heteroalkylene linking groups, no orientation of the linking group is implied by the direction in which the formula of the linking group is written. For example, the formula -C(O)<sub>2</sub>R'- represents both -C(O)<sub>2</sub>R'- and -R'C(O)<sub>2</sub>-.

[0041] In general, an “acyl substituent” is also selected from the group set forth above. As used herein, the term “acyl substituent” refers to groups attached to, and fulfilling the valence of a carbonyl carbon that is either directly or indirectly attached to the polycyclic nucleus of the compounds of the present invention.

[0042] The terms “cycloalkyl” and “heterocycloalkyl”, by themselves or in combination 30 with other terms, represent, unless otherwise stated, cyclic versions of “alkyl” and “heteroalkyl”, respectively. Additionally, for heterocycloalkyl, a heteroatom can occupy the position at which the heterocycle is attached to the remainder of the molecule. Examples of

cycloalkyl include, but are not limited to, cyclopentyl, cyclohexyl, 1-cyclohexenyl, 3-cyclohexenyl, cycloheptyl, and the like. Examples of heterocycloalkyl include, but are not limited to, 1-(1,2,5,6-tetrahydropyridyl), 1-piperidinyl, 2-piperidinyl, 3-piperidinyl, 4-morpholinyl, 3-morpholinyl, tetrahydrofuran-2-yl, tetrahydrofuran-3-yl, tetrahydrothien-2-yl, 5-tetrahydrothien-3-yl, 1-piperazinyl, 2-piperazinyl, and the like.

[0043] The terms “halo” or “halogen,” by themselves or as part of another substituent, mean, unless otherwise stated, a fluorine, chlorine, bromine, or iodine atom. Additionally, terms such as “haloalkyl,” are meant to include monohaloalkyl and polyhaloalkyl. For example, the term “halo(C<sub>1</sub>-C<sub>4</sub>)alkyl” is meant to include, but not be limited to, 10 trifluoromethyl, 2,2,2-trifluoroethyl, 4-chlorobutyl, 3-bromopropyl, and the like.

[0044] The term “aryl” means, unless otherwise stated, a polyunsaturated, aromatic, hydrocarbon substituent which can be a single ring or multiple rings (preferably from 1 to 3 rings) which are fused together or linked covalently. The term “heteroaryl” refers to aryl groups (or rings) that contain from one to four heteroatoms selected from N, O, and S, 15 wherein the nitrogen and sulfur atoms are optionally oxidized, and the nitrogen atom(s) are optionally quaternized. A heteroaryl group can be attached to the remainder of the molecule through a heteroatom. Non-limiting examples of aryl and heteroaryl groups include phenyl, 1-naphthyl, 2-naphthyl, 4-biphenyl, 1-pyrrolyl, 2-pyrrolyl, 3-pyrrolyl, 3-pyrazolyl, 2-imidazolyl, 4-imidazolyl, pyrazinyl, 2-oxazolyl, 4-oxazolyl, 2-phenyl-4-oxazolyl, 5-oxazolyl, 20 3-isoxazolyl, 4-isoxazolyl, 5-isoxazolyl, 2-thiazolyl, 4-thiazolyl, 5-thiazolyl, 2-furyl, 3-furyl, 2-thienyl, 3-thienyl, 2-pyridyl, 3-pyridyl, 4-pyridyl, 2-pyrimidyl, 4-pyrimidyl, 5-benzothiazolyl, purinyl, 2-benzimidazolyl, 5-indolyl, 1-isoquinolyl, 5-isoquinolyl, 2-quinoxaliny, 5-quinoxaliny, 3-quinolyl, and 6-quinolyl. Substituents for each of the above noted aryl and heteroaryl ring systems are selected from the group of acceptable substituents 25 described below.

[0045] For brevity, the term “aryl” when used in combination with other terms (e.g., aryloxy, arylthioxy, arylalkyl) includes both aryl and heteroaryl rings as defined above. Thus, the term “arylalkyl” is meant to include those radicals in which an aryl group is attached to an alkyl group (e.g., benzyl, phenethyl, pyridylmethyl and the like) including 30 those alkyl groups in which a carbon atom (e.g., a methylene group) has been replaced by, for example, an oxygen atom (e.g., phenoxyethyl, 2-pyridyloxymethyl, 3-(1-naphthoxy)propyl, and the like).

[0046] Each of the above terms (e.g., "alkyl," "heteroalkyl," "aryl" and "heteroaryl") include both substituted and unsubstituted forms of the indicated radical. Preferred substituents for each type of radical are provided below.

[0047] Substituents for the alkyl, and heteroalkyl radicals (including those groups often

5 referred to as alkylene, alkenyl, heteroalkylene, heteroalkenyl, alkynyl, cycloalkyl, heterocycloalkyl, cycloalkenyl, and heterocycloalkenyl) are generally referred to as "alkyl substituents" and "heteroalkyl substituents," respectively, and they can be one or more of a variety of groups selected from, but not limited to: -OR', =O, =NR', =N-OR', -NR'R", -SR', -halogen, -SiR'R'R", -OC(O)R', -C(O)R', -CO<sub>2</sub>R', -CONR'R", -OC(O)NR'R", -NR"C(O)R', -NR'-C(O)NR'R", -NR"C(O)<sub>2</sub>R', -NR-C(NR'R'R")=NR", -NR-C(NR'R")=NR", -S(O)R', -S(O)<sub>2</sub>R', -S(O)<sub>2</sub>NR'R", -NRSO<sub>2</sub>R', -CN and -NO<sub>2</sub> in a number ranging from zero to (2m'+1), where m' is the total number of carbon atoms in such radical. R', R", R'" and R"" each preferably independently refer to hydrogen, substituted or unsubstituted heteroalkyl, substituted or unsubstituted aryl, e.g., aryl substituted with 1-3 halogens, substituted or unsubstituted alkyl, alkoxy or thioalkoxy groups, or arylalkyl groups. When a compound of the invention includes more than one R group, for example, each of the R groups is independently selected as are each R', R", R'" and R"" groups when more than one of these groups is present. When R' and R" are attached to the same nitrogen atom, they can be combined with the nitrogen atom to form a 5-, 6-, or 7-membered ring. For example, -

10 NR'R" is meant to include, but not be limited to, 1-pyrrolidinyl and 4-morpholinyl. From the above discussion of substituents, one of skill in the art will understand that the term "alkyl" is meant to include groups including carbon atoms bound to groups other than hydrogen groups, such as haloalkyl (e.g., -CF<sub>3</sub> and -CH<sub>2</sub>CF<sub>3</sub>) and acyl (e.g., -C(O)CH<sub>3</sub>, -C(O)CF<sub>3</sub>, -C(O)CH<sub>2</sub>OCH<sub>3</sub>, and the like).

15

20 [0048] Similar to the substituents described for the alkyl radical, the aryl substituents and heteroaryl substituents are generally referred to as "aryl substituents" and "heteroaryl substituents," respectively and are varied and selected from, for example: halogen, -OR', =O, =NR', =N-OR', -NR'R", -SR', -halogen, -SiR'R'R", -OC(O)R', -C(O)R', -CO<sub>2</sub>R', -CONR'R", -OC(O)NR'R", -NR"C(O)R', -NR'-C(O)NR'R", -NR"C(O)<sub>2</sub>R', -NR-C(NR'R")=NR", -S(O)R', -S(O)<sub>2</sub>R', -S(O)<sub>2</sub>NR'R", -NRSO<sub>2</sub>R', -CN and -NO<sub>2</sub>, -R', -N<sub>3</sub>, -CH(Ph)<sub>2</sub>, fluoro(C<sub>1</sub>-C<sub>4</sub>)alkoxy, and fluoro(C<sub>1</sub>-C<sub>4</sub>)alkyl, in a number ranging from zero to the total number of open valences on the aromatic ring system; and where R', R", R'" and R"" are preferably independently selected from hydrogen, (C<sub>1</sub>-C<sub>8</sub>)alkyl and heteroalkyl,

unsubstituted aryl and heteroaryl, (unsubstituted aryl)-(C<sub>1</sub>-C<sub>4</sub>)alkyl, and (unsubstituted aryl)oxy-(C<sub>1</sub>-C<sub>4</sub>)alkyl. When a compound of the invention includes more than one R group, for example, each of the R groups is independently selected as are each R', R'', R''' and R'''' groups when more than one of these groups is present.

5 [0049] Two of the aryl substituents on adjacent atoms of the aryl or heteroaryl ring may optionally be replaced with a substituent of the formula -T-C(O)-(CRR')<sub>q</sub>-U-, wherein T and U are independently -NR-, -O-, -CRR'- or a single bond, and q is an integer of from 0 to 3. Alternatively, two of the substituents on adjacent atoms of the aryl or heteroaryl ring may 10 optionally be replaced with a substituent of the formula -A-(CH<sub>2</sub>)<sub>r</sub>-B-, wherein A and B are independently -CRR'-, -O-, -NR-, -S-, -S(O)-, -S(O)<sub>2</sub>-, -S(O)<sub>2</sub>NR'- or a single bond, and r is an integer of from 1 to 4. One of the single bonds of the new ring so formed may optionally be replaced with a double bond. Alternatively, two of the substituents on adjacent atoms of 15 the aryl or heteroaryl ring may optionally be replaced with a substituent of the formula -(CRR')<sub>s</sub>-X-(CR''R''')<sub>d</sub>-, where s and d are independently integers of from 0 to 3, and X is -O-, -NR'-, -S-, -S(O)-, -S(O)<sub>2</sub>-, or -S(O)<sub>2</sub>NR'-. The substituents R, R', R'' and R''' are preferably independently selected from hydrogen or substituted or unsubstituted (C<sub>1</sub>-C<sub>6</sub>)alkyl.

As used herein, the term "heteroatom" includes oxygen (O), nitrogen (N), sulfur (S) and silicon (Si).

20 [0050] The term "amino acid" refers to naturally occurring and synthetic amino acids, as well as amino acid analogs and amino acid mimetics that function in a manner similar to the naturally occurring amino acids. Naturally occurring amino acids are those encoded by the genetic code, as well as those amino acids that are later modified, *e.g.*, hydroxyproline,  $\gamma$ -carboxyglutamate, and O-phosphoserine. Amino acid analogs refers to compounds that have the same basic chemical structure as a naturally occurring amino acid, *i.e.*, an  $\alpha$  carbon that is 25 bound to a hydrogen, a carboxyl group, an amino group, and an R group, *e.g.*, homoserine, norleucine, methionine sulfoxide, methionine methyl sulfonium. Such analogs have modified R groups (*e.g.*, norleucine) or modified peptide backbones, but retain the same basic chemical structure as a naturally occurring amino acid. "Amino acid mimetics" refers to chemical 30 compounds having a structure that is different from the general chemical structure of an amino acid, but that functions in a manner similar to a naturally occurring amino acid.

[0051] There are various known methods in the art that permit the incorporation of an unnatural amino acid derivative or analog into a polypeptide chain in a site-specific manner, *see, e.g.*, WO 02/086075.

[0052] Amino acids may be referred to herein by either the commonly known three letter symbols or by the one-letter symbols recommended by the IUPAC-IUB Biochemical Nomenclature Commission. Nucleotides, likewise, may be referred to by their commonly accepted single-letter codes.

[0053] As to amino acid sequences, one of skill will recognize that individual substitutions, deletions or additions to a nucleic acid, peptide, polypeptide, or protein sequence which alters, adds or deletes a single amino acid or a small percentage of amino acids in the encoded sequence is a “conservatively modified variant” where the alteration results in the substitution of an amino acid with a chemically similar amino acid. Conservative substitution tables providing functionally similar amino acids are well known in the art. Such conservatively modified variants are in addition to and do not exclude polymorphic variants, interspecies homologs, and alleles of the invention.

[0054] The following eight groups each contain amino acids that are conservative substitutions for one another:

- 1) Alanine (A), Glycine (G);
- 2) Aspartic acid (D), Glutamic acid (E);
- 20 3) Asparagine (N), Glutamine (Q);
- 4) Arginine (R), Lysine (K);
- 5) Isoleucine (I), Leucine (L), Methionine (M), Valine (V);
- 6) Phenylalanine (F), Tyrosine (Y), Tryptophan (W);
- 7) Serine (S), Threonine (T); and
- 25 8) Cysteine (C), Methionine (M)

(*see, e.g.*, Creighton, *Proteins* (1984)).

[0055] Amino acids may be referred to herein by either their commonly known three letter symbols or by the one-letter symbols recommended by the IUPAC-IUB Biochemical Nomenclature Commission. Nucleotides, likewise, may be referred to by their commonly accepted single-letter codes.

[0056] "Peptide" refers to a polymer in which the monomers are amino acids and are joined together through amide bonds, alternatively referred to as a polypeptide. Additionally,

unnatural amino acids, for example,  $\beta$ -alanine, phenylglycine and homoarginine are also included. Amino acids that are not gene-encoded may also be used in the present invention. Furthermore, amino acids that have been modified to include reactive groups, glycosylation sites, polymers, therapeutic moieties, biomolecules and the like may also be used in the invention. All of the amino acids used in the present invention may be either the D - or L - isomer. The L -isomer is generally preferred. In addition, other peptidomimetics are also useful in the present invention. As used herein, "peptide" refers to both glycosylated and unglycosylated peptides. Also included are peptides that are incompletely glycosylated by a system that expresses the peptide. For a general review, *see*, Spatola, A. F., in **CHEMISTRY AND BIOCHEMISTRY OF AMINO ACIDS, PEPTIDES AND PROTEINS**, B. Weinstein, eds., Marcel Dekker, New York, p. 267 (1983).

[0057] The term "peptide conjugate," refers to species of the invention in which a peptide is glycoconjugated with a modified sugar as set forth herein. In a representative example, the peptide is a mutant peptide having an O-linked glycosylation site not present in the wild-type peptide.

[0058] The term "sialic acid" refers to any member of a family of nine-carbon carboxylated sugars. The most common member of the sialic acid family is N-acetyl-neuraminic acid (2-keto-5-acetamido-3,5-dideoxy-D-glycero-D-galactononulopyranos-1-onic acid (often abbreviated as Neu5Ac, NeuAc, or NANA). A second member of the family is N-glycolyl-neuraminic acid (Neu5Gc or NeuGc), in which the N-acetyl group of NeuAc is hydroxylated. A third sialic acid family member is 2-keto-3-deoxy-nonulosonic acid (KDN) (Nadano *et al.* (1986) *J. Biol. Chem.* **261**: 11550-11557; Kanamori *et al.*, *J. Biol. Chem.* **265**: 21811-21819 (1990)). Also included are 9-substituted sialic acids such as a 9-O-C<sub>1</sub>-C<sub>6</sub> acyl-Neu5Ac like 9-O-lactyl-Neu5Ac or 9-O-acetyl-Neu5Ac, 9-deoxy-9-fluoro-Neu5Ac and 9-azido-9-deoxy-Neu5Ac. For review of the sialic acid family, *see*, e.g., Varki, *Glycobiology* **2**: 25-40 (1992); *Sialic Acids: Chemistry, Metabolism and Function*, R. Schauer, Ed. (Springer-Verlag, New York (1992)). The synthesis and use of sialic acid compounds in a sialylation procedure is disclosed in international application WO 92/16640, published October 1, 1992.

[0059] As used herein, the term "modified sugar," refers to a naturally- or non-naturally- occurring carbohydrate that is enzymatically added onto an amino acid or a glycosyl residue of a peptide in a process of the invention. The modified sugar is selected from a number of enzyme substrates including, but not limited to sugar nucleotides (mono-, di-, and tri-phosphates), activated sugars (e.g., glycosyl halides, glycosyl mesylates) and sugars that are

neither activated nor nucleotides. The “modified sugar” is covalently functionalized with a “modifying group.” Useful modifying groups include, but are not limited to, water-soluble polymers, therapeutic moieties, diagnostic moieties, biomolecules and the like. The modifying group is preferably not a naturally occurring, or an unmodified carbohydrate. The 5 locus of functionalization with the modifying group is selected such that it does not prevent the “modified sugar” from being added enzymatically to a peptide.

[0060] The term “water-soluble” refers to moieties that have some detectable degree of solubility in water. Methods to detect and/or quantify water solubility are well known in the art. Exemplary water-soluble polymers include peptides, saccharides, poly(ethers), 10 poly(amines), poly(carboxylic acids) and the like. Peptides can have mixed sequences of be composed of a single amino acid, *e.g.*, poly(lysine). An exemplary polysaccharide is poly(sialic acid). An exemplary poly(ether) is poly(ethylene glycol), *e.g.*, m-PEG. Poly(ethylene imine) is an exemplary polyamine, and poly(acrylic) acid is a representative poly(carboxylic acid).

15 [0061] The polymer backbone of the water-soluble polymer can be poly(ethylene glycol) (i.e. PEG). However, it should be understood that other related polymers are also suitable for use in the practice of this invention and that the use of the term PEG or poly(ethylene glycol) is intended to be inclusive and not exclusive in this respect. The term PEG includes poly(ethylene glycol) in any of its forms, including alkoxy PEG, difunctional PEG, 20 multiarmed PEG, forked PEG, branched PEG, pendent PEG (i.e. PEG or related polymers having one or more functional groups pendent to the polymer backbone), or PEG with degradable linkages therein.

[0062] The polymer backbone can be linear or branched. Branched polymer backbones are generally known in the art. Typically, a branched polymer has a central branch core moiety 25 and a plurality of linear polymer chains linked to the central branch core. PEG is commonly used in branched forms that can be prepared by addition of ethylene oxide to various polyols, such as glycerol, pentaerythritol and sorbitol. The central branch moiety can also be derived from several amino acids, such as lysine. The branched poly(ethylene glycol) can be represented in general form as R(-PEG-OH)<sub>m</sub> in which R represents the core moiety, such as 30 glycerol or pentaerythritol, and *m* represents the number of arms. Multi-armed PEG molecules, such as those described in U.S. Pat. No. 5,932,462, which is incorporated by reference herein in its entirety, can also be used as the polymer backbone.

[0063] Many other polymers are also suitable for the invention. Polymer backbones that are non-peptidic and water-soluble, with from 2 to about 300 termini, are particularly useful in the invention. Examples of suitable polymers include, but are not limited to, other poly(alkylene glycols), such as poly(propylene glycol) ("PPG"), copolymers of ethylene glycol and propylene glycol and the like, poly(oxyethylated polyol), poly(olefinic alcohol), poly(vinylpyrrolidone), poly(hydroxypropylmethacrylamide), poly( $\alpha$ -hydroxy acid), poly(vinyl alcohol), polyphosphazene, polyoxazoline, poly(N-acryloylmorpholine), such as described in U.S. Pat. No. 5,629,384, which is incorporated by reference herein in its entirety, and copolymers, terpolymers, and mixtures thereof. Although the molecular weight of each chain of the polymer backbone can vary, it is typically in the range of from about 100 Da to about 100,000 Da, often from about 6,000 Da to about 80,000 Da.

[0064] The term "glycoconjugation," as used herein, refers to the enzymatically mediated conjugation of a modified sugar species to an amino acid or glycosyl residue of a polypeptide, *e.g.*, a mutant human growth hormone of the present invention. A subgenus of "glycoconjugation" is "glyco-PEGylation," in which the modifying group of the modified sugar is poly(ethylene glycol), and alkyl derivative (*e.g.*, m-PEG) or reactive derivative (*e.g.*, H<sub>2</sub>N-PEG, HOOC-PEG, etc.) thereof.

[0065] The terms "large-scale" and "industrial-scale" are used interchangeably and refer to a reaction cycle that produces at least about 250 mg, preferably at least about 500 mg, and more preferably at least about 1 gram of glycoconjugate at the completion of a single reaction cycle.

[0066] The term, "glycosyl linking group," as used herein refers to a glycosyl residue to which a modifying group (*e.g.*, PEG moiety, therapeutic moiety, biomolecule) is covalently attached; the glycosyl linking group joins the modifying group to the remainder of the conjugate. In the methods of the invention, the "glycosyl linking group" becomes covalently attached to a glycosylated or unglycosylated peptide, thereby linking the agent to an amino acid and/or glycosyl residue on the peptide. A "glycosyl linking group" is generally derived from a "modified sugar" by the enzymatic attachment of the "modified sugar" to an amino acid and/or glycosyl residue of the peptide, or to a glycosyl moiety or aglycone residue of a glycolipid. The glycosyl linking group can also be a saccharide-derived structure that is degraded during formation of modifying group-modified sugar cassette (*e.g.*, oxidation→Schiff base formation→reduction). The resulting conjugate is enzymatically added to the peptide, glycopeptide, aglycone, glycolipid, etc. Alternatively, the glycosyl

linking group may be intact. An “intact glycosyl linking group” refers to a linking group that is derived from a glycosyl moiety in which the saccharide monomer that links the modifying group and to the remainder of the conjugate is not degraded, e.g., oxidized, e.g., by sodium metaperiodate to create a locus of attachment for the modifying group. “Intact glycosyl

5 linking groups” of the invention may be derived from a naturally occurring oligosaccharide by addition of glycosyl unit(s) or removal of one or more glycosyl unit from a parent saccharide structure.

[0067] The term “targeting moiety,” as used herein, refers to species that will selectively localize in a particular tissue or region of the body. The localization is mediated by specific  
10 recognition of molecular determinants, molecular size of the targeting agent or conjugate, ionic interactions, hydrophobic interactions and the like. Other mechanisms of targeting an agent to a particular tissue or region are known to those of skill in the art. Exemplary targeting moieties include antibodies, antibody fragments, transferrin, HS-glycoprotein, coagulation factors, serum proteins,  $\beta$ -glycoprotein, G-CSF, GM-CSF, M-CSF, EPO and the  
15 like.

[0068] As used herein, “therapeutic moiety” means any agent useful for therapy including, but not limited to, antibiotics, anti-inflammatory agents, anti-tumor drugs, cytotoxins, and radioactive agents. “Therapeutic moiety” includes prodrugs of bioactive agents, constructs in which more than one therapeutic moiety is bound to a carrier, e.g, multivalent agents.

20 Therapeutic moiety also includes proteins and constructs that include proteins. Exemplary proteins include, but are not limited to, Erythropoietin (EPO), Granulocyte Colony Stimulating Factor (GCSF), Granulocyte Macrophage Colony Stimulating Factor (GMCSF), Interferon (e.g., Interferon- $\alpha$ , - $\beta$ , - $\gamma$ ), Interleukin (e.g., Interleukin II), serum proteins (e.g., Factors VII, VIIa, VIII, IX, and X), Human Chorionic Gonadotropin (HCG), Follicle  
25 Stimulating Hormone (FSH) and Lutenizing Hormone (LH) and antibody fusion proteins (e.g. Tumor Necrosis Factor Receptor ((TNFR)/Fc domain fusion protein)).

[0069] As used herein, “anti-tumor drug” means any agent useful to combat cancer including, but not limited to, cytotoxins and agents such as antimetabolites, alkylating agents, anthracyclines, antibiotics, antimitotic agents, procarbazine, hydroxyurea, asparaginase,  
30 corticosteroids, interferons and radioactive agents. Also encompassed within the scope of the term “anti-tumor drug,” are conjugates of peptides with anti-tumor activity, e.g. TNF- $\alpha$ . Conjugates include, but are not limited to those formed between a therapeutic protein and a

glycoprotein of the invention. A representative conjugate is that formed between PSGL-1 and TNF- $\alpha$ .

[0070] As used herein, "a cytotoxin or cytotoxic agent" means any agent that is detrimental to cells. Examples include taxol, cytochalasin B, gramicidin D, ethidium bromide, emetine,

5 mitomycin, etoposide, tenoposide, vincristine, vinblastine, colchicin, doxorubicin, daunorubicin, dihydroxy anthracenedione, mitoxantrone, mithramycin, actinomycin D, 1-dehydrotestosterone, glucocorticoids, procaine, tetracaine, lidocaine, propranolol, and puromycin and analogs or homologs thereof. Other toxins include, for example, ricin, CC-1065 and analogues, the duocarmycins. Still other toxins include diphtheria toxin, and snake

10 venom (e.g., cobra venom).

[0071] As used herein, "a radioactive agent" includes any radioisotope that is effective in diagnosing or destroying a tumor. Examples include, but are not limited to, indium-111, cobalt-60. Additionally, naturally occurring radioactive elements such as uranium, radium, and thorium, which typically represent mixtures of radioisotopes, are suitable examples of a

15 radioactive agent. The metal ions are typically chelated with an organic chelating moiety.

[0072] Many useful chelating groups, crown ethers, cryptands and the like are known in the art and can be incorporated into the compounds of the invention (e.g., EDTA, DTPA, DOTA, NTA, HDTA, etc. and their phosphonate analogs such as DTPP, EDTP, HDTP, NTP, etc.).

See, for example, Pitt *et al.*, "The Design of Chelating Agents for the Treatment of Iron

20 Overload," In, INORGANIC CHEMISTRY IN BIOLOGY AND MEDICINE; Martell, Ed.; American Chemical Society, Washington, D.C., 1980, pp. 279-312; Lindoy, THE CHEMISTRY OF MACROCYCLIC LIGAND COMPLEXES; Cambridge University Press, Cambridge, 1989; Dugas, BIOORGANIC CHEMISTRY; Springer-Verlag, New York, 1989, and references contained therein.

25 [0073] Additionally, a manifold of routes allowing the attachment of chelating agents, crown ethers and cyclodextrins to other molecules is available to those of skill in the art. See, for example, Meares *et al.*, "Properties of In Vivo Chelate-Tagged Proteins and Polypeptides." In, MODIFICATION OF PROTEINS: FOOD, NUTRITIONAL, AND PHARMACOLOGICAL ASPECTS;" Feeney, *et al.*, Eds., American Chemical Society, Washington, D.C., 1982, pp. 370-387; Kasina *et al.*, *Bioconjugate Chem.*, 9: 108-117 (1998); Song *et al.*, *Bioconjugate Chem.*, 8: 249-255 (1997).

[0074] As used herein, "pharmaceutically acceptable carrier" includes any material, which when combined with the conjugate retains the conjugates' activity and is non-reactive with the subject's immune systems. Examples include, but are not limited to, any of the standard pharmaceutical carriers such as a phosphate buffered saline solution, water, emulsions such as oil/water emulsion, and various types of wetting agents. Other carriers may also include sterile solutions, tablets including coated tablets and capsules. Typically such carriers contain excipients such as starch, milk, sugar, certain types of clay, gelatin, stearic acid or salts thereof, magnesium or calcium stearate, talc, vegetable fats or oils, gums, glycols, or other known excipients. Such carriers may also include flavor and color additives or other ingredients. Compositions comprising such carriers are formulated by well known conventional methods.

[0075] As used herein, "administering" means oral administration, administration as a suppository, topical contact, intravenous, intraperitoneal, intramuscular, intralesional, or subcutaneous administration, administration by inhalation, or the implantation of a slow-release device, *e.g.*, a mini-osmotic pump, to the subject. Administration is by any route including parenteral and transmucosal (*e.g.*, oral, nasal, vaginal, rectal, or transdermal), particularly by inhalation. Parenteral administration includes, *e.g.*, intravenous, intramuscular, intra-arteriole, intradermal, subcutaneous, intraperitoneal, intraventricular, and intracranial. Moreover, where injection is to treat a tumor, *e.g.*, induce apoptosis, administration may be directly to the tumor and/or into tissues surrounding the tumor. Other modes of delivery include, but are not limited to, the use of liposomal formulations, intravenous infusion, transdermal patches, etc.

[0076] The term "isolated" refers to a material that is substantially or essentially free from components, which are used to produce the material. For peptide conjugates of the invention, the term "isolated" refers to material that is substantially or essentially free from components, which normally accompany the material in the mixture used to prepare the peptide conjugate. "Isolated" and "pure" are used interchangeably. Typically, isolated peptide conjugates of the invention have a level of purity preferably expressed as a range. The lower end of the range of purity for the peptide conjugates is about 60%, about 70% or about 80% and the upper end of the range of purity is about 70%, about 80%, about 90% or more than about 90%.

[0077] When the peptide conjugates are more than about 90% pure, their purities are also preferably expressed as a range. The lower end of the range of purity is about 90%, about

92%, about 94%, about 96% or about 98%. The upper end of the range of purity is about 92%, about 94%, about 96%, about 98% or about 100% purity.

[0078] Purity is determined by any art-recognized method of analysis (e.g., band intensity on a silver stained gel, polyacrylamide gel electrophoresis, HPLC, or a similar means).

5 [0079] “Essentially each member of the population,” as used herein, describes a characteristic of a population of peptide conjugates of the invention in which a selected percentage of the modified sugars added to a peptide are added to multiple, identical acceptor sites on the peptide. “Essentially each member of the population” speaks to the “homogeneity” of the sites on the peptide conjugated to a modified sugar and refers to 10 conjugates of the invention, which are at least about 80%, preferably at least about 90% and more preferably at least about 95% homogenous.

15 [0080] “Homogeneity,” refers to the structural consistency across a population of acceptor moieties to which the modified sugars are conjugated. Thus, in a peptide conjugate of the invention in which each modified sugar moiety is conjugated to an acceptor site having the same structure as the acceptor site to which every other modified sugar is conjugated, the peptide conjugate is said to be about 100% homogeneous. Homogeneity is typically expressed as a range. The lower end of the range of homogeneity for the peptide conjugates is about 60%, about 70% or about 80% and the upper end of the range of purity is about 70%, about 80%, about 90% or more than about 90%.

20 [0081] When the peptide conjugates are more than or equal to about 90% homogeneous, their homogeneity is also preferably expressed as a range. The lower end of the range of homogeneity is about 90%, about 92%, about 94%, about 96% or about 98%. The upper end of the range of purity is about 92%, about 94%, about 96%, about 98% or about 100% homogeneity. The purity of the peptide conjugates is typically determined by one or more 25 methods known to those of skill in the art, e.g., liquid chromatography-mass spectrometry (LC-MS), matrix assisted laser desorption mass time of flight spectrometry (MALDITOF), capillary electrophoresis, and the like.

[0082] “Substantially uniform glycoform” or a “substantially uniform glycosylation pattern,” when referring to a glycopeptide species, refers to the percentage of acceptor 30 moieties that are glycosylated by the glycosyltransferase of interest (e.g., fucosyltransferase). For example, in the case of a  $\alpha$ 1,2 fucosyltransferase, a substantially uniform fucosylation

pattern exists if substantially all (as defined below) of the Gal $\beta$ 1,4-GlcNAc-R and sialylated analogues thereof are fucosylated in a peptide conjugate of the invention. It will be understood by one of skill in the art, that the starting material may contain glycosylated acceptor moieties (e.g., fucosylated Gal $\beta$ 1,4-GlcNAc-R moieties). Thus, the calculated

5 percent glycosylation will include acceptor moieties that are glycosylated by the methods of the invention, as well as those acceptor moieties already glycosylated in the starting material.

[0083] The term "substantially" in the above definitions of "substantially uniform" generally means at least about 40%, at least about 70%, at least about 80%, or more preferably at least about 90%, and still more preferably at least about 95% of the acceptor

10 moieties for a particular glycosyltransferase are glycosylated.

### Introduction

[0084] The present invention provides modified sugars and activated modified sugars that are substrates for an enzyme that transfers the activated modified sugars onto an amino acid or glycosyl residue of a peptide or glycopeptide, or onto a glycosyl residue of a glycolipid, or

15 an aglycone, e.g., sphingosine, ceramide, etc. The invention also provides glycoconjugates formed using the activated modified sugars of the invention. Also provided are methods for producing the conjugates of the invention. The invention also provides pharmaceutical formulations that include a conjugate formed by a method of the invention.

[0085] The conjugates of the invention are formed between a therapeutic core molecule, e.g., peptides, glycolipids and aglycones, and diverse species such as water-soluble polymers, therapeutic moieties, diagnostic moieties, targeting moieties and the like. Also provided are conjugates that include two or more peptides linked together through a linker arm, *i.e.*, multifunctional conjugates. The multi-functional conjugates of the invention can include two or more copies of the same peptide or a collection of diverse peptides with different

20 structures and/or properties. In exemplary conjugates according to this embodiment, the linker between the two peptides is attached to at least one of the peptides through a glycosyl linking group.

25

[0086] The conjugates of the invention are formed by the enzymatic conjugation of a modified sugar of the invention to the glycosylated or unglycosylated peptide. The modified sugar is directly added to an amino acid of a glycosylation site, or to a glycosyl residue attached either directly or indirectly (e.g., through one or more glycosyl residue) to a

30 glycosylation site.

[0087] The modified sugar, when interposed between the peptide (or glycosyl residue) and the modifying group on the sugar becomes what is referred to herein as a “glycosyl linking group,” e.g., “an intact glycosyl linking group.” Using the exquisite selectivity of enzymes, such as glycosyltransferases, the present method provides peptides that bear a desired group 5 at one or more specific locations. Thus, according to the present invention, a modified sugar is attached directly to a selected locus on the peptide chain or, alternatively, the modified sugar is appended onto a carbohydrate moiety of a glycopeptide. Peptides in which modified sugars are bound to both a glycopeptide carbohydrate and directly to an amino acid residue of the peptide backbone are also within the scope of the present invention.

10 [0088] The invention also provides a method for preparing a conjugate using a modified activated sugar of the invention. The method includes contacting a peptide, glycolipid, or aglycone (e.g., sphingosine or ceramide) with an activated modified sugar and an enzyme for which the activated modified sugar is a substrate, which transfers the modified glycosyl component of the activated sugar onto an amino acid or glycosyl residue of a peptide, or a 15 glycosyl or heteroatom moiety of a glycolipid or aglycone.

[0089] In contrast to known chemical and enzymatic peptide elaboration strategies, the methods of the invention, make it possible to assemble peptides, glycopeptides and glycolipids that have a substantially homogeneous derivatization pattern; the enzymes used in the invention are generally selective for a particular amino acid residue or combination of 20 amino acid residues of the peptide. The methods are also practical for large-scale production of modified peptides, glycopeptides and glycolipids. Thus, the methods of the invention provide a practical means for large-scale preparation of glycopeptides and glycolipids having preselected uniform derivatization patterns. The methods are particularly well suited for modification of therapeutic peptides, including but not limited to, glycopeptides that are 25 incompletely glycosylated during production in cell culture cells (e.g., mammalian cells, insect cells, plant cells, fungal cells, yeast cells, or prokaryotic cells) or transgenic plants or animals.

[0090] The methods of the invention also provide conjugates of glycosylated and unglycosylated peptides, and glycolipids, with increased therapeutic half-life due to, for 30 example, reduced clearance rate, or reduced rate of uptake by the immune or reticuloendothelial system (RES). Moreover, the methods of the invention provide a means for masking antigenic determinants on peptides, thus reducing or eliminating a host immune

response against the peptide. Selective attachment of targeting agents to a peptide or glycolipid using an appropriate modified sugar can also be used to target the peptide or glycolipid to a particular tissue or cell surface receptor that is specific for the particular targeting agent. Moreover, there is provided a class of peptides and glycolipids that are 5 specifically modified with a therapeutic moiety conjugated through a glycosyl linking group.

Modified Sugars

[0091] The present invention provides a class of modified sugars and modified sugar nucleotides in which the sugar moiety is a N-acyl sugar. The sugar moiety is further functionalized with a modifying group. The modifying group is conjugated to the sugar 10 moiety, typically, via an amine, sulfhydryl or primary hydroxyl moiety on the sugar. In an exemplary embodiment, the modifying group is attached through an amine moiety on the sugar, which is converted to an amide, a urethane or a urea through its reaction with a reactive derivative of the modifying group.

[0092] In an exemplary embodiment, the amine moiety is appended to the 6-carbon atom 15 and the N-acyl moiety is appended to the 2-carbon atom. As will be apparent to those of skill in the art, both the amine moiety and the N-acyl group (e.g., substituted or unsubstituted C<sub>1</sub>-C<sub>6</sub> acyl, e.g., methyl) can be located at any position on the sugar nucleus.

[0093] Any sugar can be utilized as the sugar core of the conjugates of the invention. Exemplary sugar cores that are useful in forming the compositions of the invention include, 20 but are not limited to, glucose, galactose, mannose, fucose, and sialic acid. Also encompassed within the invention are species in which the sugar core is a disaccharide, an oligosaccharide or a polysaccharide.

[0094] Modified glycosyl donor species (“modified sugars”) are preferably selected from modified sugar nucleotides.

25 *Water-Soluble Polymers*

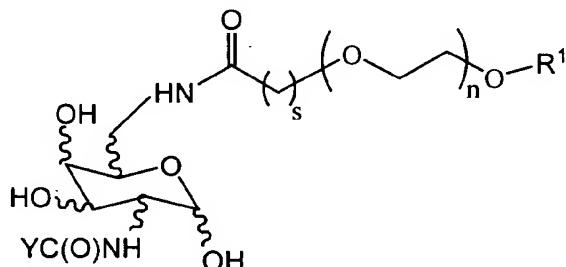
[0095] In an exemplary embodiment, the modifying group is a PEG moiety, however, any modifying group, e.g., water-soluble polymer, water-insoluble polymer, therapeutic moiety, etc., can be incorporated in a N-acetyl sugar amine through an amide linkage. The PEG-amide modified sugar is formed by enzymatic means, chemical means or a combination 30 thereof, thereby producing a modified sugar. The sugars are substituted with an active amine at any position that allows for the attachment of the modifying moiety, yet which still allows

the sugar to function as a substrate for an enzyme capable of coupling the modified sugar to the peptide. In an exemplary embodiment, when galactosamine is the modified sugar, the amine moiety is attached to the carbon atom at the 6-position.

[0096] Thus, in another exemplary embodiment, the invention provides a saccharide that

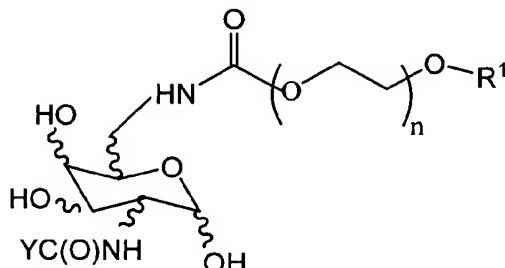
5 includes a saccharyl core that is derivatized with a N-acetyl moiety. The core is also functionalized with a  $-Z-R-(CH_2CH_2O)_nCH_2CH_2OR^1$  or  $-C(O)-Z-R-(CH_2CH_2O)_nCH_2CH_2OR^1$  moiety, typically at C-6. The symbol R represents  $C(O)(CH_2)_mO$ ,  $C(O)NH(CH_2)_mO$ , or  $C(O)O(CH_2)_mO$ . Z includes groups such as O, S, N and NH. The index m is an integer from 0 to 20.  $R^1$  is a member selected from H, substituted or 10 unsubstituted alkyl (e.g., alkylaryl) and substituted or unsubstituted aryl; and n is an integer selected from 1 or greater, typically from 1 to 2500. In a still further exemplary embodiment, the N-acetyl moiety is attached to C-2 of said saccharide.

[0097] Another exemplary saccharide of the invention has the structure:



15 in which n is an integer from 1 to 2500; and s is an integer from 1 to 20, preferably, 2 to 4. Y is a substituted or unsubstituted alkyl moiety, e.g. C<sub>1</sub>-C<sub>6</sub> alkyl, such as methyl. R<sup>1</sup> is as discussed above.

[0098] In another exemplary embodiment, the invention provides a conjugate having the structure:



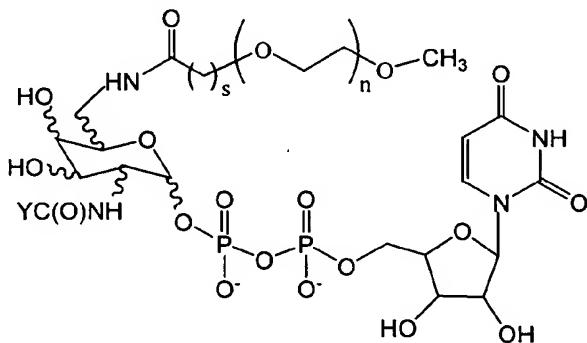
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[0099] In certain embodiments of the present invention, there are provided modified sugar nucleotides. Exemplary sugar nucleotides that are used in the present invention in their modified form include nucleotide mono-, di- or triphosphates or analogs thereof. In a

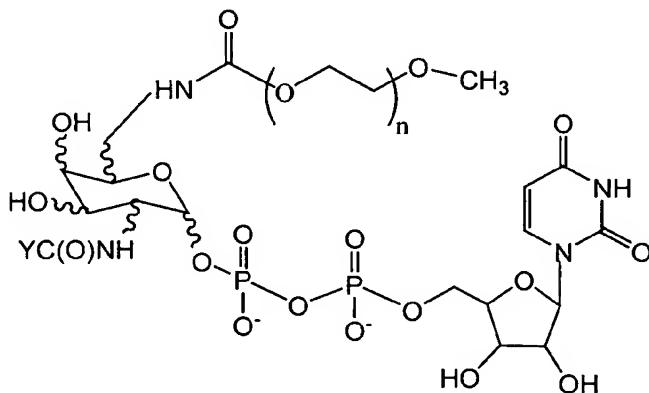
preferred embodiment, the modified sugar nucleotide is selected from a UDP-glycoside, CMP-glycoside, or a GDP-glycoside. Even more preferably, the modified sugar nucleotide is selected from an UDP-galactose, UDP-galactosamine, UDP-glucose, UDP-glucosamine, GDP-mannose, GDP-fucose, CMP-sialic acid, or CMP-NeuAc. In an exemplary embodiment, the nucleotide phosphate is attached to C-1.

[0100] The saccharyl-amine derivatives of the sugar nucleotides are also of use in the method of the invention. For example, the saccharyl amine (without the modifying group) can be enzymatically conjugated to a peptide (or other species) and the free saccharyl amine moiety subsequently conjugated to a desired modifying group.

10 [0101] A further exemplary saccharide of the invention has the structure:



[0102] In a still further exemplary embodiment, the invention provides a conjugate having the structure:



15 [0103] The wavy lines in the formulae above indicate that the stereochemistry of the saccharyl core is not specified.

[0104] Methods and chemistry for activation of water-soluble polymers and saccharides as well as methods for conjugating saccharides and polymers to various species are described in

the literature. Commonly used methods for activation of polymers include activation of functional groups with cyanogen bromide, periodate, glutaraldehyde, biepoxides, epichlorohydrin, divinylsulfone, carbodiimide, sulfonyl halides, trichlorotriazine, *etc.* (see, R. F. Taylor, (1991), PROTEIN IMMOBILISATION. FUNDAMENTALS AND APPLICATIONS, Marcel Dekker, N.Y.; S. S. Wong, (1992), CHEMISTRY OF PROTEIN CONJUGATION AND CROSSLINKING, CRC Press, Boca Raton; G. T. Hermanson *et al.*, (1993), IMMOBILIZED AFFINITY LIGAND TECHNIQUES, Academic Press, N.Y.; Dunn, R.L., *et al.*, Eds. POLYMERIC DRUGS AND DRUG DELIVERY SYSTEMS, ACS Symposium Series Vol. 469, American Chemical Society, Washington, D.C. 1991).

10 [0105] Routes for preparing reactive PEG molecules and forming conjugates using the reactive molecules are known in the art. For example, U.S. Patent No. 5,672,662 discloses a water soluble and isolatable conjugate of an active ester of a polymer acid selected from linear or branched poly(alkylene oxides), poly(oxyethylated polyols), poly(olefinic alcohols), and poly(acrylomorpholine), wherein the polymer has about 44 or more recurring units.

15 [0106] U.S. Patent No. 6,376,604 sets forth a method for preparing a water-soluble 1-benzotriazolylcarbonate ester of a water-soluble and non-peptidic polymer by reacting a terminal hydroxyl of the polymer with di(1-benzotriazolyl)carbonate in an organic solvent. The active ester is used to form conjugates with a biologically active agent such as a protein or peptide.

20 [0107] WO 99/45964 describes a conjugate comprising a biologically active agent and an activated water soluble polymer comprising a polymer backbone having at least one terminus linked to the polymer backbone through a stable linkage, wherein at least one terminus comprises a branching moiety having proximal reactive groups linked to the branching moiety, in which the biologically active agent is linked to at least one of the proximal reactive groups. Other branched poly(ethylene glycols) are described in WO 96/21469, U.S. Patent 25 No. 5,932,462 describes a conjugate formed with a branched PEG molecule that includes a branched terminus that includes reactive functional groups. The free reactive groups are available to react with a biologically active species, such as a protein or peptide, forming conjugates between the poly(ethylene glycol) and the biologically active species. U.S. Patent No. 5,446,090 describes a bifunctional PEG linker and its use in forming conjugates having a peptide at each of the PEG linker termini.

[0108] Conjugates that include degradable PEG linkages are described in WO 99/34833; and WO 99/14259, as well as in U.S. Patent No. 6,348,558. Such degradable linkages are applicable in the present invention.

[0109] Although both reactive PEG derivatives and conjugates formed using the derivatives are known in the art, until the present invention, it was not recognized that a conjugate could be formed between PEG (or other polymer) and another species, such as a peptide or glycopeptide, through an intact glycosyl linking group.

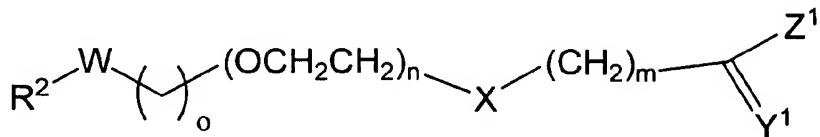
[0110] Many water-soluble polymers are known to those of skill in the art and are useful in practicing the present invention. The term water-soluble polymer encompasses species such as saccharides (e.g., dextran, amylose, hyalouronic acid, poly(sialic acid), heparans, heparins, etc.); poly (amino acids); nucleic acids; synthetic polymers (e.g., poly(acrylic acid), poly(ethers), e.g., poly(ethylene glycol); peptides, proteins, and the like. The present invention may be practiced with any water-soluble polymer with the sole limitation that the polymer must include a point at which the remainder of the conjugate can be attached.

[0111] Methods for activation of polymers can also be found in WO 94/17039, U.S. Pat. No. 5,324,844, WO 94/18247, WO 94/04193, U.S. Pat. No. 5,219,564, U.S. Pat. No. 5,122,614, WO 90/13540, U.S. Pat. No. 5,281,698, and more WO 93/15189, and for conjugation between activated polymers and peptides, e.g. Coagulation Factor VIII (WO 94/15625), hemoglobin (WO 94/09027), oxygen carrying molecule (U.S. Pat. No. 4,412,989), ribonuclease and superoxide dismutase (Veronese *et al.*, *App. Biochem. Biotech.* 11: 141-45 (1985)).

[0112] Preferred water-soluble polymers are those in which a substantial proportion of the polymer molecules in a sample of the polymer are of approximately the same molecular weight; such polymers are “homodisperse.”

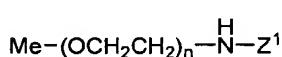
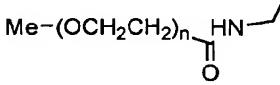
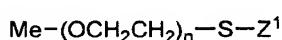
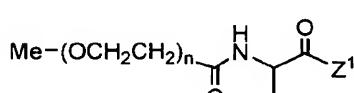
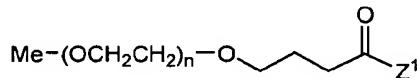
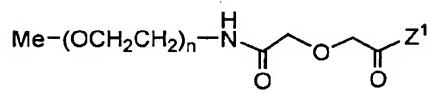
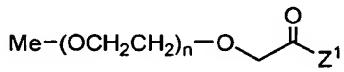
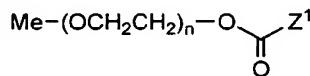
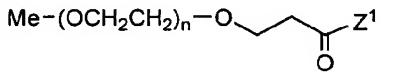
[0113] The present invention is further illustrated by reference to a poly(ethylene glycol) conjugate. Several reviews and monographs on the functionalization and conjugation of PEG are available. See, for example, Harris, *Macromol. Chem. Phys.* C25: 325-373 (1985); Scouten, *Methods in Enzymology* 135: 30-65 (1987); Wong *et al.*, *Enzyme Microb. Technol.* 14: 866-874 (1992); Delgado *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems* 9: 249-304 (1992); Zalipsky, *Bioconjugate Chem.* 6: 150-165 (1995); and Bhadra, *et al.*, *Pharmazie*, 57:5-29 (2002).

[0114] Exemplary poly(ethylene glycol) molecules suitable for use in the invention include, but are not limited to, those species set forth below.

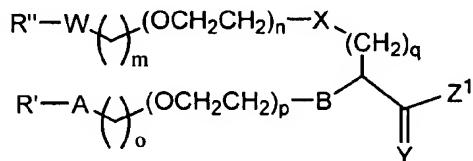


in which R<sup>2</sup> is H, substituted or unsubstituted alkyl, substituted or unsubstituted aryl, 5 substituted or unsubstituted heteroaryl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted heteroalkyl, e.g., acetal, OHC-, H<sub>2</sub>N-CH<sub>2</sub>CH<sub>2</sub>-, HS-CH<sub>2</sub>CH<sub>2</sub>-, and-(CH<sub>2</sub>)<sub>q</sub>C(Y<sup>1</sup>)Z<sup>2</sup>; -sugar-nucleotide, or protein. The index "n" represents an integer from 1 to 2500. The indeces m, o, and q independently represent integers from 0 to 20. The symbol Z represents OH, NH<sub>2</sub>, halogen, S-R<sup>3</sup>, the alcohol portion of activated esters, 10 -(CH<sub>2</sub>)<sub>p</sub>C(Y<sup>2</sup>)V, -(CH<sub>2</sub>)<sub>p</sub>U(CH<sub>2</sub>)<sub>s</sub>C(Y<sup>2</sup>)<sub>v</sub>, sugar-nucleotide, protein, and activating groups, e.g., imidazole, p-nitrophenyl, HOBT, tetrazole, halide. The symbols X, Y<sup>1</sup>, Y<sup>2</sup>, W, U independently represent the moieties O, S, N-R<sup>4</sup>. The symbol V represents OH, NH<sub>2</sub>, 15 halogen, S-R<sup>5</sup>, the alcohol component of activated esters, the amine component of activated amides, sugar-nucleotide, and protein. The indeces p, s and v are members independently selected from the integers from 0 to 20. The symbols R<sup>3</sup>, R<sup>4</sup> and R<sup>5</sup> independently represent H, substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heterocycloalkyl and substituted or unsubstituted heteroaryl.

[0115] In exemplary embodiments, the poly(ethylene glycol) molecule is selected from the 20 following:



[0116] The poly(ethylene glycol) useful in forming the conjugate of the invention is either linear or branched. Branched poly(ethylene glycol) molecules suitable for use in the invention include, but are not limited to, those described by the following Formula:

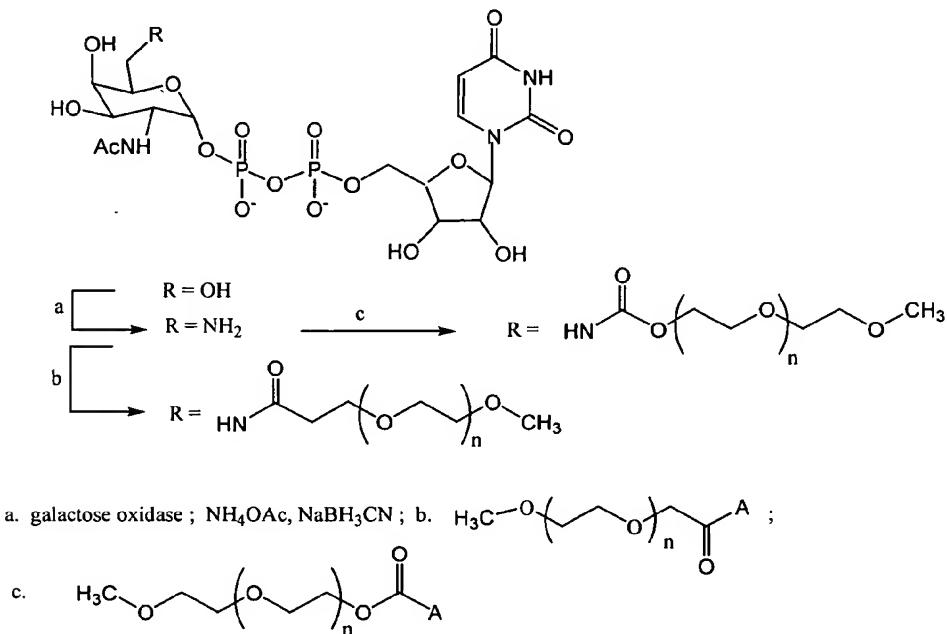


5 in which the symbols are as described above.

[0117] In other exemplary embodiments, the branched PEG is based upon a cysteine, serine or di-lysine core. Thus, further exemplary branched PEGs include:

PEG-S-Cys-NHC(O)-OPEG; PEG-O-Ser-NHC(O)-OPEG or  
(PEGO-C(O)NH)<sub>2</sub>Lys-Lys-NHC(O)-OPEG.

10 [0118] In an exemplary embodiment, the modified sugar is based upon a 6-amino-N-acetyl-glycosyl moiety. As shown below for N-acetylgalactosamine, the 6-amino-sugar moiety is readily prepared by standard methods.



[0119] In the scheme above, the index n represents an integer from 1 to 2500, preferably from 10 to 1500, and more preferably from 10 to 1200. The symbol "A" represents an activating group, e.g., a halo, an activated ester (e.g., a N-hydroxysuccinimide ester), a

carbonate (e.g., p-nitrophenyl carbonate) and the like. Those of skill in the art will appreciate that other PEG-amide nucleotide sugars are readily prepared by this and analogous methods.

[0120] In other exemplary embodiments, the amide moiety is replaced by a group such as a urethane or a urea.

5 *Water-insoluble polymers*

[0121] In another embodiment, analogous to those discussed above, the modified sugars include a water-insoluble polymer, rather than a water-soluble polymer. The conjugates of the invention may also include one or more water-insoluble polymers. This embodiment of the invention is illustrated by the use of the conjugate as a vehicle with which to deliver a therapeutic peptide in a controlled manner. Polymeric drug delivery systems are known in the art. *See, for example, Dunn et al., Eds. POLYMERIC DRUGS AND DRUG DELIVERY SYSTEMS, ACS Symposium Series Vol. 469, American Chemical Society, Washington, D.C. 1991.* Those of skill in the art will appreciate that substantially any known drug delivery system is applicable to the conjugates of the present invention.

15 [0122] Representative water-insoluble polymers include, but are not limited to, polyphosphazines, poly(vinyl alcohols), polyamides, polycarbonates, polyalkylenes, polyacrylamides, polyalkylene glycols, polyalkylene oxides, polyalkylene terephthalates, polyvinyl ethers, polyvinyl esters, polyvinyl halides, polyvinylpyrrolidone, polyglycolides, polysiloxanes, polyurethanes, poly(methyl methacrylate), poly(ethyl methacrylate),  
20 poly(butyl methacrylate), poly(isobutyl methacrylate), poly(hexyl methacrylate), poly(isodecyl methacrylate), poly(lauryl methacrylate), poly(phenyl methacrylate), poly(methyl acrylate), poly(isopropyl acrylate), poly(isobutyl acrylate), poly(octadecyl acrylate) polyethylene, polypropylene, poly(ethylene glycol), poly(ethylene oxide), poly(ethylene terephthalate), poly(vinyl acetate), polyvinyl chloride, polystyrene, polyvinyl  
25 pyrrolidone, pluronic and polyvinylphenol and copolymers thereof.

[0123] Synthetically modified natural polymers of use in conjugates of the invention include, but are not limited to, alkyl celluloses, hydroxyalkyl celluloses, cellulose ethers, cellulose esters, and nitrocelluloses. Particularly preferred members of the broad classes of synthetically modified natural polymers include, but are not limited to, methyl cellulose, ethyl cellulose, hydroxypropyl cellulose, hydroxypropyl methyl cellulose, hydroxybutyl methyl cellulose, cellulose acetate, cellulose propionate, cellulose acetate butyrate, cellulose

acetate phthalate, carboxymethyl cellulose, cellulose triacetate, cellulose sulfate sodium salt, and polymers of acrylic and methacrylic esters and alginic acid.

[0124] These and the other polymers discussed herein can be readily obtained from commercial sources such as Sigma Chemical Co. (St. Louis, MO.), Polysciences (Warrenton, PA.), Aldrich (Milwaukee, WI.), Fluka (Ronkonkoma, NY), and BioRad (Richmond, CA), or else synthesized from monomers obtained from these suppliers using standard techniques.

[0125] Representative biodegradable polymers of use in the conjugates of the invention include, but are not limited to, polylactides, polyglycolides and copolymers thereof, poly(ethylene terephthalate), poly(butyric acid), poly(valeric acid), poly(lactide-co-caprolactone), poly(lactide-co-glycolide), polyanhydrides, polyorthoesters, blends and copolymers thereof. Of particular use are compositions that form gels, such as those including collagen, pluronic and the like.

[0126] The polymers of use in the invention include "hybrid" polymers that include water-insoluble materials having within at least a portion of their structure, a bioresorbable molecule. An example of such a polymer is one that includes a water-insoluble copolymer, which has a bioresorbable region, a hydrophilic region and a plurality of crosslinkable functional groups per polymer chain.

[0127] For purposes of the present invention, "water-insoluble materials" includes materials that are substantially insoluble in water or water-containing environments. Thus, although certain regions or segments of the copolymer may be hydrophilic or even water-soluble, the polymer molecule, as a whole, does not to any substantial measure dissolve in water.

[0128] For purposes of the present invention, the term "bioresorbable molecule" includes a region that is capable of being metabolized or broken down and resorbed and/or eliminated through normal excretory routes by the body. Such metabolites or break down products are preferably substantially non-toxic to the body.

[0129] The bioresorbable region may be either hydrophobic or hydrophilic, so long as the copolymer composition as a whole is not rendered water-soluble. Thus, the bioresorbable region is selected based on the preference that the polymer, as a whole, remains water-insoluble. Accordingly, the relative properties, *i.e.*, the kinds of functional groups contained

by, and the relative proportions of the bioresorbable region, and the hydrophilic region are selected to ensure that useful bioresorbable compositions remain water-insoluble.

[0130] Exemplary resorbable polymers include, for example, synthetically produced resorbable block copolymers of poly( $\alpha$ -hydroxy-carboxylic acid)/poly(oxyalkylene, (see, 5 Cohn *et al.*, U.S. Patent No. 4,826,945). These copolymers are not crosslinked and are water-soluble so that the body can excrete the degraded block copolymer compositions. See, Younes *et al.*, *J Biomed. Mater. Res.* **21**: 1301-1316 (1987); and Cohn *et al.*, *J Biomed. Mater. Res.* **22**: 993-1009 (1988).

[0131] Presently preferred bioresorbable polymers include one or more components 10 selected from poly(esters), poly(hydroxy acids), poly(lactones), poly(amides), poly(ester-amides), poly (amino acids), poly(anhydrides), poly(orthoesters), poly(carbonates), poly(phosphazines), poly(phosphoesters), poly(thioesters), polysaccharides and mixtures thereof. More preferably still, the biosresorbable polymer includes a poly(hydroxy) acid component. Of the poly(hydroxy) acids, polylactic acid, polyglycolic acid, polycaproic acid, 15 polybutyric acid, polyvaleric acid and copolymers and mixtures thereof are preferred.

[0132] In addition to forming fragments that are absorbed *in vivo* ("bioresorbed"), preferred polymeric coatings for use in the methods of the invention can also form an excretable and/or metabolizable fragment.

[0133] Higher order copolymers can also be used in the present invention. For example, 20 Casey *et al.*, U.S. Patent No. 4,438,253, which issued on March 20, 1984, discloses tri-block copolymers produced from the transesterification of poly(glycolic acid) and an hydroxyl-ended poly(alkylene glycol). Such compositions are disclosed for use as resorbable monofilament sutures. The flexibility of such compositions is controlled by the incorporation 25 of an aromatic orthocarbonate, such as tetra-p-tolyl orthocarbonate into the copolymer structure.

[0134] Other polymers based on lactic and/or glycolic acids can also be utilized. For example, Spinu, U.S. Patent No. 5,202,413, which issued on April 13, 1993, discloses biodegradable multi-block copolymers having sequentially ordered blocks of polylactide and/or polyglycolide produced by ring-opening polymerization of lactide and/or glycolide 30 onto either an oligomeric diol or a diamine residue followed by chain extension with a di-functional compound, such as, a diisocyanate, diacylchloride or dichlorosilane.

[0135] Bioresorbable regions of coatings useful in the present invention can be designed to be hydrolytically and/or enzymatically cleavable. For purposes of the present invention, "hydrolytically cleavable" refers to the susceptibility of the copolymer, especially the bioresorbable region, to hydrolysis in water or a water-containing environment. Similarly, 5 "enzymatically cleavable" as used herein refers to the susceptibility of the copolymer, especially the bioresorbable region, to cleavage by endogenous or exogenous enzymes.

[0136] When placed within the body, the hydrophilic region can be processed into excretable and/or metabolizable fragments. Thus, the hydrophilic region can include, for example, polyethers, polyalkylene oxides, polyols, poly(vinyl pyrrolidine), poly(vinyl 10 alcohol), poly(alkyl oxazolines), polysaccharides, carbohydrates, peptides, proteins and copolymers and mixtures thereof. Furthermore, the hydrophilic region can also be, for example, a poly(alkylene) oxide. Such poly(alkylene) oxides can include, for example, poly(ethylene) oxide, poly(propylene) oxide and mixtures and copolymers thereof.

[0137] Polymers that are components of hydrogels are also useful in the present invention. 15 Hydrogels are polymeric materials that are capable of absorbing relatively large quantities of water. Examples of hydrogel forming compounds include, but are not limited to, polyacrylic acids, sodium carboxymethylcellulose, polyvinyl alcohol, polyvinyl pyrrolidine, gelatin, carrageenan and other polysaccharides, hydroxyethylenemethacrylic acid (HEMA), as well as derivatives thereof, and the like. Hydrogels can be produced that are stable, biodegradable 20 and bioresorbable. Moreover, hydrogel compositions can include subunits that exhibit one or more of these properties.

[0138] Bio-compatible hydrogel compositions whose integrity can be controlled through crosslinking are known and are presently preferred for use in the methods of the invention. For example, Hubbell *et al.*, U.S. Patent Nos. 5,410,016, which issued on April 25, 1995 and 25 5,529,914, which issued on June 25, 1996, disclose water-soluble systems, which are crosslinked block copolymers having a water-soluble central block segment sandwiched between two hydrolytically labile extensions. Such copolymers are further end-capped with photopolymerizable acrylate functionalities. When crosslinked, these systems become hydrogels. The water soluble central block of such copolymers can include poly(ethylene 30 glycol); whereas, the hydrolytically labile extensions can be a poly( $\alpha$ -hydroxy acid), such as polyglycolic acid or polylactic acid. *See, Sawhney et al., Macromolecules 26: 581-587 (1993).*

[0139] In another preferred embodiment, the gel is a thermoreversible gel. Thermoreversible gels including components, such as pluronics, collagen, gelatin, hyalouronic acid, polysaccharides, polyurethane hydrogel, polyurethane-urea hydrogel and combinations thereof are presently preferred.

5 [0140] In yet another exemplary embodiment, the conjugate of the invention includes a component of a liposome. Liposomes can be prepared according to methods known to those skilled in the art, for example, as described in Eppstein *et al.*, U.S. Patent No. 4,522,811, which issued on June 11, 1985. For example, liposome formulations may be prepared by dissolving appropriate lipid(s) (such as stearoyl phosphatidyl ethanolamine, stearoyl  
10 phosphatidyl choline, arachadoyl phosphatidyl choline, and cholesterol) in an inorganic solvent that is then evaporated, leaving behind a thin film of dried lipid on the surface of the container. An aqueous solution of the active compound or its pharmaceutically acceptable salt is then introduced into the container. The container is then swirled by hand to free lipid material from the sides of the container and to disperse lipid aggregates, thereby forming the  
15 liposomal suspension.

[0141] The above-recited microparticles and methods of preparing the microparticles are offered by way of example and they are not intended to define the scope of microparticles of use in the present invention. It will be apparent to those of skill in the art that an array of microparticles, fabricated by different methods, are of use in the present invention.

20 The Methods

[0142] In addition to the conjugates discussed above, the present invention provides methods for preparing these and other conjugates. Moreover, the invention provides methods of preventing, curing or ameliorating a disease state by administering a conjugate of the invention to a subject at risk of developing the disease or a subject that has the disease.

25 [0143] Thus, the invention provides a method of forming a covalent conjugate between a selected moiety and a peptide, a glycolipid or an aglycone (e.g., ceramide or sphingosine). For clarity of illustration, the invention is illustrated with reference to a conjugate formed between a peptide and the modified glycosyl moiety of an activated modified sugar of the invention. Those of skill will appreciate that the invention equally encompasses methods of  
30 forming conjugates of glycolipids, and aglycones with an activated modified sugar of the invention.

[0144] In exemplary embodiments, the conjugate is formed between a water-soluble polymer, a therapeutic moiety, targeting moiety or a biomolecule, and a glycosylated or non-glycosylated peptide. The polymer, therapeutic moiety or biomolecule is conjugated to the peptide via a glycosyl linking group, which is interposed between, and covalently linked to both the peptide and the modifying group (e.g., water-soluble polymer). The method includes contacting the peptide with a mixture containing a modified sugar and an enzyme, e.g., a glycosyltransferase, that conjugates the modified sugar to the substrate (e.g., peptide, aglycone, glycolipid). The reaction is conducted under conditions appropriate to form a covalent bond between the modified sugar and the peptide (or other substrate). The sugar moiety of the modified sugar is preferably selected from nucleotide sugars.

[0145] The acceptor peptide is typically synthesized *de novo*, or recombinantly expressed in a prokaryotic cell (e.g., bacterial cell, such as *E. coli*) or in a eukaryotic cell such as a mammalian, yeast, insect, fungal or plant cell. The peptide can be either a full-length protein or a fragment. Moreover, the peptide can be a wild type or mutated peptide. In an exemplary embodiment, the peptide includes a mutation that adds one or more N- or O-linked glycosylation sites to the peptide sequence.

[0146] The method of the invention also provides for modification of incompletely glycosylated peptides that are produced recombinantly. Many recombinantly produced glycoproteins are incompletely glycosylated, exposing carbohydrate residues that may have undesirable properties, e.g., immunogenicity, recognition by the RES. Employing a modified sugar in a method of the invention, the peptide can be simultaneously further glycosylated and derivatized with, e.g., a water-soluble polymer, therapeutic agent, or the like. The sugar moiety of the modified sugar can be the residue that would properly be conjugated to the acceptor in a fully glycosylated peptide, or another sugar moiety with desirable properties.

[0147] Exemplary peptides that can be modified using the methods of the invention are set forth in Table 1.

Table 1

<u>Hormones and Growth</u>	<u>Receptors and Chimeric</u>
<u>Factors</u>	<u>Receptors</u>
<ul style="list-style-type: none"> <li>• G-CSF</li> <li>• GM-CSF</li> <li>• M-CSF</li> <li>• TPO</li> <li>• EPO</li> <li>• EPO variants</li> <li>• alpha-TNF</li> <li>• Leptin</li> </ul>	<ul style="list-style-type: none"> <li>• CD4</li> <li>• Tumor Necrosis Factor (TNF) receptor</li> <li>• Alpha-CD20</li> <li>• MAb-CD20</li> <li>• MAb-alpha-CD3</li> <li>• MAb-TNF receptor</li> <li>• MAb-CD4</li> <li>• PSGL-1</li> <li>• MAb-PSGL-1</li> <li>• Complement</li> <li>• GlyCAM or its chimera</li> <li>• N-CAM or its chimera</li> </ul>
<u>Enzymes and Inhibitors</u>	<u>Monoclonal Antibodies</u>
<ul style="list-style-type: none"> <li>• t-PA</li> <li>• t-PA variants</li> <li>• Urokinase</li> <li>• Factors VII, VIII, IX, X</li> <li>• Dnase</li> <li>• Glucocerebrosidase</li> <li>• Hirudin</li> <li>• <math>\alpha</math>1 antitrypsin</li> <li>• Antithrombin III</li> </ul>	<u>(Immunoglobulins)</u> <ul style="list-style-type: none"> <li>• MAb-anti-RSV</li> <li>• MAb-anti-IL-2 receptor</li> <li>• MAb-anti-CEA</li> <li>• MAb-anti-platelet IIb/IIIa receptor</li> <li>• MAb-anti-EGF</li> <li>• MAb-anti-Her-2 receptor</li> </ul>
<u>Cytokines and Chimeric</u>	<u>Cells</u>
<u>Cytokines</u>	
<ul style="list-style-type: none"> <li>• Interleukin-1 (IL-1), 1B, 2, 3, 4</li> <li>• Interferon-alpha (IFN-alpha)</li> <li>• IFN-alpha-2b</li> <li>• IFN-beta</li> <li>• IFN-gamma</li> <li>• Chimeric diphtheria toxin-IL-2</li> </ul>	<ul style="list-style-type: none"> <li>• Red blood cells</li> <li>• White blood cells (e.g., T cells, B cells, dendritic cells, macrophages, NK cells, neutrophils, monocytes and the like</li> <li>• Stem cells</li> </ul>

[0148] Other exemplary peptides that are modified by the methods of the invention include members of the immunoglobulin family (e.g., antibodies, MHC molecules, T cell receptors, and the like), intercellular receptors (e.g., integrins, receptors for hormones or growth factors and the like) lectins, and cytokines (e.g., interleukins). Additional examples include tissue-type plasminogen activator (t-PA), renin, clotting factors such as factors V-XII, bombesin, thrombin, hematopoietic growth factor, colony stimulating factors, viral antigens, complement proteins,  $\alpha$ 1-antitrypsin, erythropoietin, P-selectin glycopeptide ligand-1 (PSGL-1), granulocyte-macrophage colony stimulating factor, anti-thrombin III, interleukins, interferons, proteins A and C, fibrinogen, herceptin, leptin, glycosidases, HS-glycoprotein, serum proteins (e.g.,  $\alpha$ -acid glycoprotein, fetuin,  $\alpha$ -fetal protein),  $\beta$ 2-glycoprotein, among many others. This list of polypeptides is exemplary, not exclusive. The methods are also

useful for modifying fusion and chimeric proteins, including, but not limited to, chimeric proteins that include a moiety derived from an immunoglobulin, such as IgG, or a fragment of an immunoglobulin, e.g., FAb (Fc domain). The exemplary peptides provided herein are intended to provide a selection of the peptides with which the present invention can be practiced; as such, they are non-limiting. Those of skill will appreciate that the invention can be practiced using substantially any peptide from any source.

[0149] Peptides modified by the methods of the invention can be synthetic or wild-type peptides or they can be mutated peptides, produced by methods known in the art, such as site-directed mutagenesis. Glycosylation of peptides is typically either N-linked or O-linked. An exemplary N-linkage is the attachment of the modified sugar to the side chain of an asparagine residue. The tripeptide sequences asparagine-X-serine and asparagine-X-threonine, where X is any amino acid except proline, are the recognition sequences for enzymatic attachment of a carbohydrate moiety to the asparagine side chain. Thus, the presence of either of these tripeptide sequences in a polypeptide creates a potential glycosylation site. O-linked glycosylation refers to the attachment of one sugar (e.g., N-acetylgalactosamine, galactose, mannose, GlcNAc, glucose, fucose or xylose) to the hydroxy side chain of a hydroxyamino acid, preferably serine or threonine, although unusual or non-natural amino acids, e.g., 5-hydroxyproline or 5-hydroxylysine may also be used.

[0150] Moreover, in addition to peptides, the methods of the present invention can be practiced with other biological structures (e.g., glycolipids, lipids, sphingoids, ceramides, whole cells, and the like, containing a glycosylation site).

[0151] Addition of glycosylation sites to a peptide or other structure is conveniently accomplished by altering the amino acid sequence such that it contains one or more glycosylation sites. The addition may also be made by the incorporation of one or more species presenting an -OH group, preferably serine or threonine residues, within the sequence of the peptide (for O-linked glycosylation sites). The addition may be made by mutation or by full chemical synthesis of the peptide. The peptide amino acid sequence is preferably altered through changes at the DNA level, particularly by mutating the DNA encoding the peptide at preselected bases such that codons are generated that will translate into the desired amino acids. The DNA mutation(s) are preferably made using methods known in the art.

[0152] In an exemplary embodiment, the glycosylation site is added by shuffling polynucleotides. Polynucleotides encoding a candidate peptide can be modulated with DNA

shuffling protocols. DNA shuffling is a process of recursive recombination and mutation, performed by random fragmentation of a pool of related genes, followed by reassembly of the fragments by a polymerase chain reaction-like process. *See, e.g., Stemmer, Proc. Natl. Acad. Sci. USA* 91:10747-10751 (1994); Stemmer, *Nature* 370:389-391 (1994); and U.S. Patent Nos. 5,605,793, 5,837,458, 5,830,721 and 5,811,238.

5 [0153] The present invention also provides means of adding (or removing) one or more selected glycosyl residues to a peptide, after which a modified sugar is conjugated to at least one of the selected glycosyl residues of the peptide. The present embodiment is useful, for example, when it is desired to conjugate the modified sugar to a selected glycosyl residue that 10 is either not present on a peptide or is not present in a desired amount. Thus, prior to coupling a modified sugar to a peptide, the selected glycosyl residue is conjugated to the peptide by enzymatic or chemical coupling. In another embodiment, the glycosylation pattern of a glycopeptide is altered prior to the conjugation of the modified sugar by the removal of a carbohydrate residue from the glycopeptide. *See, for example WO 98/31826.*

15 [0154] Addition or removal of any carbohydrate moieties present on the glycopeptide is accomplished either chemically or enzymatically. Chemical deglycosylation is preferably brought about by exposure of the polypeptide variant to the compound trifluoromethanesulfonic acid, or an equivalent compound. This treatment results in the cleavage of most or all sugars except the linking sugar (N-acetylglucosamine or N-acetylgalactosamine), while leaving the peptide intact. Chemical deglycosylation is 20 described by Hakimuddin *et al.*, *Arch. Biochem. Biophys.* 259: 52 (1987) and by Edge *et al.*, *Anal. Biochem.* 118: 131 (1981). Enzymatic cleavage of carbohydrate moieties on polypeptide variants can be achieved by the use of a variety of endo- and exo-glycosidases as described by Thotakura *et al.*, *Meth. Enzymol.* 138: 350 (1987).

25 [0155] Chemical addition of glycosyl moieties is carried out by any art-recognized method. Enzymatic addition of sugar moieties is preferably achieved using a modification of the methods set forth herein, substituting native glycosyl units for the modified sugars used in the invention. Other methods of adding sugar moieties are disclosed in U.S. Patent No. 5,876,980, 6,030,815, 5,728,554, and 5,922,577.

30 [0156] Exemplary attachment points for selected glycosyl residue include, but are not limited to: (a) consensus sites for N-linked glycosylation, and sites for O-linked glycosylation; (b) terminal glycosyl moieties that are acceptors for a glycosyltransferase; (c)

arginine, asparagine and histidine; (d) free carboxyl groups; (e) free sulfhydryl groups such as those of cysteine; (f) free hydroxyl groups such as those of serine, threonine, or hydroxyproline; (g) aromatic residues such as those of phenylalanine, tyrosine, or tryptophan; or (h) the amide group of glutamine. Exemplary methods of use in the present invention are 5 described in WO 87/05330 published Sep. 11, 1987, and in Aplin and Wriston, CRC CRIT. REV. BIOCHEM., pp. 259-306 (1981).

[0157] In one embodiment, the invention provides a method for linking two or more peptides through a linking group. The linking group is of any useful structure and may be selected from straight- and branched-chain structures. Preferably, each terminus of the 10 linker, which is attached to a peptide, includes a modified sugar (i.e., a nascent intact glycosyl linking group).

[0158] In an exemplary method of the invention, two peptides are linked together via a linker moiety that includes a polymeric (e.g., PEG linker). The construct conforms to the general structure set forth in the cartoon above. As described herein, the construct of the 15 invention includes two intact glycosyl linking groups (i.e.,  $s + t = 1$ ). The focus on a PEG linker that includes two glycosyl groups is for purposes of clarity and should not be interpreted as limiting the identity of linker arms of use in this embodiment of the invention.

[0159] Thus, a PEG moiety is functionalized at a first terminus with a first glycosyl unit and at a second terminus with a second glycosyl unit. The first and second glycosyl units are 20 preferably substrates for different transferases, allowing orthogonal attachment of the first and second peptides to the first and second glycosyl units, respectively. In practice, the (glycosyl)<sup>1</sup>-PEG-(glycosyl)<sup>2</sup> linker is contacted with the first peptide and a first transferase for which the first glycosyl unit is a substrate, thereby forming (peptide)<sup>1</sup>-(glycosyl)<sup>1</sup>-PEG-(glycosyl)<sup>2</sup>. Transferase and/or unreacted peptide is then 25 optionally removed from the reaction mixture. The second peptide and a second transferase for which the second glycosyl unit is a substrate are added to the (peptide)<sup>1</sup>-(glycosyl)<sup>1</sup>-PEG-(glycosyl)<sup>2</sup> conjugate, forming (peptide)<sup>1</sup>-(glycosyl)<sup>1</sup>-PEG-(glycosyl)<sup>2</sup>-(peptide)<sup>2</sup>; at least one of the glycosyl residues is either directly or indirectly O-linked. Those of skill in the art will appreciate that the method 30 outlined above is also applicable to forming conjugates between more than two peptides by, for example, the use of a branched PEG, dendrimer, poly(amino acid), polysaccharide or the like.

Enzymes

*Glycosyltransferases*

[0160] Glycosyltransferases catalyze the addition of activated sugars (donor NDP-sugars), in a step-wise fashion, to a protein, glycopeptide, lipid or glycolipid or to the non-reducing 5 end of a growing oligosaccharide. N-linked glycopeptides are synthesized via a transferase and a lipid-linked oligosaccharide donor Dol-PP-NAG<sub>2</sub>Glc<sub>3</sub>Man<sub>9</sub> in an en block transfer followed by trimming of the core. In this case the nature of the "core" saccharide is somewhat different from subsequent attachments. A very large number of glycosyltransferases are known in the art.

10 [0161] The glycosyltransferase to be used in the present invention may be any as long as it can utilize the modified sugar as a sugar donor. Examples of such enzymes include Leloir pathway glycosyltransferase, such as galactosyltransferase, N-acetylglucosaminyltransferase, N-acetylgalactosaminyltransferase, fucosyltransferase, sialyltransferase,mannosyltransferase, xylosyltransferase, glucurononyltransferase and the like.

15 [0162] For enzymatic saccharide syntheses that involve glycosyltransferase reactions, glycosyltransferase can be cloned, or isolated from any source. Many cloned glycosyltransferases are known, as are their polynucleotide sequences. *See, e.g., "The WWW Guide To Cloned Glycosyltransferases,"* ([http://www.vei.co.uk/TGN/gt\\_guide.htm](http://www.vei.co.uk/TGN/gt_guide.htm)). Glycosyltransferase amino acid sequences and nucleotide sequences encoding 20 glycosyltransferases from which the amino acid sequences can be deduced are also found in various publicly available databases, including GenBank, Swiss-Prot, EMBL, and others.

[0163] Glycosyltransferases that can be employed in the methods of the invention include, but are not limited to, galactosyltransferases, fucosyltransferases, glucosyltransferases, N-acetylgalactosaminyltransferases, N-acetylglucosaminyltransferases, glucuronyltransferases, 25 sialyltransferases,mannosyltransferases, glucuronic acid transferases, galacturonic acid transferases, and oligosaccharyltransferases. Suitable glycosyltransferases include those obtained from eukaryotes, as well as from prokaryotes.

[0164] DNA encoding glycosyltransferases may be obtained by chemical synthesis, by screening reverse transcripts of mRNA from appropriate cells or cell line cultures, by 30 screening genomic libraries from appropriate cells, or by combinations of these procedures. Screening of mRNA or genomic DNA may be carried out with oligonucleotide probes generated from the glycosyltransferases gene sequence. Probes may be labeled with a

detectable group such as a fluorescent group, a radioactive atom or a chemiluminescent group in accordance with known procedures and used in conventional hybridization assays. In the alternative, glycosyltransferases gene sequences may be obtained by use of the polymerase chain reaction (PCR) procedure, with the PCR oligonucleotide primers being produced from 5 the glycosyltransferases gene sequence. *See*, U.S. Pat. No. 4,683,195 to Mullis *et al.* and U.S. Pat. No. 4,683,202 to Mullis.

[0165] The glycosyltransferase may be synthesized in host cells transformed with vectors containing DNA encoding the glycosyltransferases enzyme. Vectors are used either to amplify DNA encoding the glycosyltransferases enzyme and/or to express DNA which 10 encodes the glycosyltransferases enzyme. An expression vector is a replicable DNA construct in which a DNA sequence encoding the glycosyltransferases enzyme is operably linked to suitable control sequences capable of effecting the expression of the glycosyltransferases enzyme in a suitable host. The need for such control sequences will vary depending upon the host selected and the transformation method chosen. Generally, 15 control sequences include a transcriptional promoter, an optional operator sequence to control transcription, a sequence encoding suitable mRNA ribosomal binding sites, and sequences which control the termination of transcription and translation. Amplification vectors do not require expression control domains. All that is needed is the ability to replicate in a host, usually conferred by an origin of replication, and a selection gene to facilitate recognition of 20 transformants.

[0166] In an exemplary embodiment, the invention utilizes a prokaryotic enzyme. Such glycosyltransferases include enzymes involved in synthesis of lipooligosaccharides (LOS), which are produced by many gram negative bacteria (Preston *et al.*, *Critical Reviews in Microbiology* 23(3): 139-180 (1996)). Such enzymes include, but are not limited to, the 25 proteins of the *rfa* operons of species such as *E. coli* and *Salmonella typhimurium*, which include a  $\beta$ 1,6 galactosyltransferase and a  $\beta$ 1,3 galactosyltransferase (*see, e.g.*, EMBL Accession Nos. M80599 and M86935 (*E. coli*); EMBL Accession No. S56361 (*S. typhimurium*)), a glucosyltransferase (Swiss-Prot Accession No. P25740 (*E. coli*), an  $\beta$ 1,2-glucosyltransferase (*rfaJ*)(Swiss-Prot Accession No. P27129 (*E. coli*) and Swiss-Prot 30 Accession No. P19817 (*S. typhimurium*)), and an  $\beta$ 1,2-N-acetylglucosaminyltransferase (*rfaK*)(EMBL Accession No. U00039 (*E. coli*)). Other glycosyltransferases for which amino acid sequences are known include those that are encoded by operons such as *rfaB*, which have been characterized in organisms such as *Klebsiella pneumoniae*, *E. coli*, *Salmonella*

*typhimurium*, *Salmonella enterica*, *Yersinia enterocolitica*, *Mycobacterium leprae*, and the *rh1* operon of *Pseudomonas aeruginosa*.

[0167] Also suitable for use in the present invention are glycosyltransferases that are involved in producing structures containing lacto-N-neotetraose, D-galactosyl- $\beta$ -1,4-N-

5 acetyl-D-glucosaminyl- $\beta$ -1,3-D-galactosyl- $\beta$ -1,4-D-glucose, and the P<sup>k</sup> blood group trisaccharide sequence, D-galactosyl- $\alpha$ -1,4-D-galactosyl- $\beta$ -1,4-D-glucose, which have been identified in the LOS of the mucosal pathogens *Neisseria gonorrhoeae* and *N. meningitidis* (Scholten *et al.*, *J. Med. Microbiol.* **41**: 236-243 (1994)). The genes from *N. meningitidis* and *N. gonorrhoeae* that encode the glycosyltransferases involved in the biosynthesis of these

10 structures have been identified from *N. meningitidis* immunotypes L3 and L1 (Jennings *et al.*, *Mol. Microbiol.* **18**: 729-740 (1995)) and the *N. gonorrhoeae* mutant F62 (Gotshlich, *J. Exp. Med.* **180**: 2181-2190 (1994)). In *N. meningitidis*, a locus consisting of three genes, *lgtA*, *lgtB* and *lgtE*, encodes the glycosyltransferase enzymes required for addition of the last three of the sugars in the lacto-N-neotetraose chain (Wakarchuk *et al.*, *J. Biol. Chem.* **271**: 19166-

15 73 (1996)). Recently the enzymatic activity of the *lgtB* and *lgtA* gene product was demonstrated, providing the first direct evidence for their proposed glycosyltransferase function (Wakarchuk *et al.*, *J. Biol. Chem.* **271**(45): 28271-276 (1996)). In *N. gonorrhoeae*, there are two additional genes, *lgtD* which adds  $\beta$ -D-GalNAc to the 3 position of the terminal galactose of the lacto-N-neotetraose structure and *lgtC* which adds a terminal  $\alpha$ -D-Gal to the

20 lactose element of a truncated LOS, thus creating the P<sup>k</sup> blood group antigen structure (Gotshlich (1994), *supra*). In *N. meningitidis*, a separate immunotype L1 also expresses the P<sup>k</sup> blood group antigen and has been shown to carry an *lgtC* gene (Jennings *et al.*, (1995), *supra*). *Neisseria* glycosyltransferases and associated genes are also described in USPN 5,545,553 (Gotschlich). Genes for  $\alpha$ 1,2-fucosyltransferase and  $\alpha$ 1,3-fucosyltransferase from

25 *Helicobacter pylori* has also been characterized (Martin *et al.*, *J. Biol. Chem.* **272**: 21349-21356 (1997)). Also of use in the present invention are the glycosyltransferases of *Campylobacter jejuni* (see, for example, [http://afmb.cnrs-mrs.fr/~pedro/CAZY/gtf\\_42.html](http://afmb.cnrs-mrs.fr/~pedro/CAZY/gtf_42.html)).

a) *Fucosyltransferases*

[0168] In some embodiments, a glycosyltransferase used in the method of the invention is a

30 fucosyltransferase. Fucosyltransferases are known to those of skill in the art. Exemplary fucosyltransferases include enzymes, which transfer L-fucose from GDP-fucose to a hydroxy

position of an acceptor sugar. Fucosyltransferases that transfer non-nucleotide sugars to an acceptor are also of use in the present invention.

[0169] In some embodiments, the acceptor sugar is, for example, the GlcNAc in a Gal $\beta$ (1 $\rightarrow$ 3,4)GlcNAc $\beta$ - group in an oligosaccharide glycoside. Suitable fucosyltransferases for this reaction include the Gal $\beta$ (1 $\rightarrow$ 3,4)GlcNAc $\beta$ 1- $\alpha$ (1 $\rightarrow$ 3,4)fucosyltransferase (FTIII E.C. No. 2.4.1.65), which was first characterized from human milk (see, Palcic, *et al.*, *Carbohydrate Res.* **190**: 1-11 (1989); Prieels, *et al.*, *J. Biol. Chem.* **256**: 10456-10463 (1981); and Nunez, *et al.*, *Can. J. Chem.* **59**: 2086-2095 (1981)) and the Gal $\beta$ (1 $\rightarrow$ 4)GlcNAc $\beta$ - $\alpha$ fucosyltransferases (FTIV, FTV, FTVI) which are found in human serum. FTVII (E.C. No. 2.4.1.65), a sialyl  $\alpha$ (2 $\rightarrow$ 3)Gal $\beta$ ((1 $\rightarrow$ 3)GlcNAc $\beta$  fucosyltransferase, has also been characterized. A recombinant form of the Gal $\beta$ (1 $\rightarrow$ 3,4) GlcNAc $\beta$ - $\alpha$ (1 $\rightarrow$ 3,4)fucosyltransferase has also been characterized (see, Dumas, *et al.*, *Bioorg. Med. Letters* **1**: 425-428 (1991) and Kukowska-Latallo, *et al.*, *Genes and Development* **4**: 1288-1303 (1990)). Other exemplary fucosyltransferases include, for example,  $\alpha$ 1,2 fucosyltransferase (E.C. No. 2.4.1.69). Enzymatic fucosylation can be carried out by the methods described in Mollicone, *et al.*, *Eur. J. Biochem.* **191**: 169-176 (1990) or U.S. Patent No. 5,374,655. Cells that are used to produce a fucosyltransferase will also include an enzymatic system for synthesizing GDP-fucose.

*b) Galactosyltransferases*

[0170] In another group of embodiments, the glycosyltransferase is a galactosyltransferase. Exemplary galactosyltransferases include  $\alpha$ (1,3) galactosyltransferases (E.C. No. 2.4.1.151, see, e.g., Dabkowski *et al.*, *Transplant Proc.* **25**:2921 (1993) and Yamamoto *et al.* *Nature* **345**: 229-233 (1990), bovine (GenBank j04989, Joziasse *et al.*, *J. Biol. Chem.* **264**: 14290-14297 (1989)), murine (GenBank m26925; Larsen *et al.*, *Proc. Nat'l. Acad. Sci. USA* **86**: 8227-8231 (1989)), porcine (GenBank L36152; Strahan *et al.*, *Immunogenetics* **41**: 101-105 (1995)). Another suitable  $\alpha$ 1,3 galactosyltransferase is that which is involved in synthesis of the blood group B antigen (EC 2.4.1.37, Yamamoto *et al.*, *J. Biol. Chem.* **265**: 1146-1151 (1990) (human)). Yet a further exemplary galactosyltransferase is core Gal-T1.

[0171] Also suitable for use in the methods of the invention are  $\beta$ (1,4) galactosyltransferases, which include, for example, EC 2.4.1.90 (LacNAc synthetase) and EC 2.4.1.22 (lactose synthetase) (bovine (D'Agostaro *et al.*, *Eur. J. Biochem.* **183**: 211-217

(1989)), human (Masri *et al.*, *Biochem. Biophys. Res. Commun.* **157**: 657-663 (1988)), murine (Nakazawa *et al.*, *J. Biochem.* **104**: 165-168 (1988)), as well as E.C. 2.4.1.38 and the ceramide galactosyltransferase (EC 2.4.1.45, Stahl *et al.*, *J. Neurosci. Res.* **38**: 234-242 (1994)). Other suitable galactosyltransferases include, for example,  $\alpha$ 1,2 galactosyltransferases (from *e.g.*, *Schizosaccharomyces pombe*, Chapell *et al.*, *Mol. Biol. Cell* **5**: 519-528 (1994)).

5 *c) Sialyltransferases*

[0172] Sialyltransferases are another type of glycosyltransferase that is useful in the recombinant cells and reaction mixtures of the invention. Cells that produce recombinant 10 sialyltransferases will also produce CMP-sialic acid, which is a sialic acid donor for sialyltransferases. Examples of sialyltransferases that are suitable for use in the present invention include ST3Gal III (*e.g.*, a rat or human ST3Gal III), ST3Gal IV, ST3Gal I, ST6Gal I, ST3Gal V, ST6Gal II, ST6GalNAc I, ST6GalNAc II, and ST6GalNAc III (the sialyltransferase nomenclature used herein is as described in Tsuji *et al.*, *Glycobiology* **6**: v-xiv (1996)). An exemplary  $\alpha$ (2,3)sialyltransferase referred to as  $\alpha$ (2,3)sialyltransferase (EC 15 2.4.99.6) transfers sialic acid to the non-reducing terminal Gal of a Gal $\beta$ 1 $\rightarrow$ 3Glc disaccharide or glycoside. *See*, Van den Eijnden *et al.*, *J. Biol. Chem.* **256**: 3159 (1981), Weinstein *et al.*, *J. Biol. Chem.* **257**: 13845 (1982) and Wen *et al.*, *J. Biol. Chem.* **267**: 21011 (1992). Another exemplary  $\alpha$ 2,3-sialyltransferase (EC 2.4.99.4) transfers sialic acid to the non-reducing 20 terminal Gal of the disaccharide or glycoside. *see*, Rearick *et al.*, *J. Biol. Chem.* **254**: 4444 (1979) and Gillespie *et al.*, *J. Biol. Chem.* **267**: 21004 (1992). Further exemplary enzymes include Gal- $\beta$ -1,4-GlcNAc  $\alpha$ -2,6 sialyltransferase (*See*, Kurosawa *et al.* *Eur. J. Biochem.* **219**: 375-381 (1994)).

[0173] Preferably, for glycosylation of carbohydrates of glycopeptides the sialyltransferase 25 will be able to transfer sialic acid to the sequence Gal $\beta$ 1,4GlcNAc-, the most common penultimate sequence underlying the terminal sialic acid on fully sialylated carbohydrate structures (*see*, Table 1).

**Table 1: Sialyltransferases which use the Gal $\beta$ 1,4GlcNAc sequence as an acceptor substrate**

Sialyltransferase	Source	Sequence(s) formed	Ref.
ST6Gal I	Mammalian	NeuAc $\square$ 2,6Gal $\beta$ 1,4GlcNAc-	1
ST3Gal III	Mammalian	NeuAc $\square$ 2,3Gal $\beta$ 1,4GlcNAc- NeuAc $\square$ 2,3Gal $\beta$ 1,3GlcNAc-	1
ST3Gal IV	Mammalian	NeuAc $\square$ 2,3Gal $\beta$ 1,4GlcNAc- NeuAc $\square$ 2,3Gal $\beta$ 1,3GlcNAc-	1
ST6Gal II	Mammalian	NeuAc $\square$ 2,6Gal $\beta$ 1,4GlcNAc-	
ST6Gal II	photobacterium	NeuAc $\square$ 2,6Gal $\beta$ 1,4GlcNAc-	2
ST3Gal V	<i>N. meningitidis</i> <i>N. gonorrhoeae</i>	NeuAc $\square$ 2,3Gal $\beta$ 1,4GlcNAc-	3

1) Goochee *et al.*, *Bio/Technology* **9**: 1347-1355 (1991)

2) Yamamoto *et al.*, *J. Biochem.* **120**: 104-110 (1996)

5 3) Gilbert *et al.*, *J. Biol. Chem.* **271**: 28271-28276 (1996)

[0174] An example of a sialyltransferase that is useful in the claimed methods is ST3Gal III, which is also referred to as  $\alpha$ (2,3)sialyltransferase (EC 2.4.99.6). This enzyme catalyzes the transfer of sialic acid to the Gal of a Gal $\beta$ 1,3GlcNAc or Gal $\beta$ 1,4GlcNAc glycoside (see, e.g., Wen *et al.*, *J. Biol. Chem.* **267**: 21011 (1992); Van den Eijnden *et al.*, *J. Biol. Chem.* **10 256**: 3159 (1991)) and is responsible for sialylation of asparagine-linked oligosaccharides in glycopeptides. The sialic acid is linked to a Gal with the formation of an  $\alpha$ -linkage between the two saccharides. Bonding (linkage) between the saccharides is between the 2-position of NeuAc and the 3-position of Gal. This particular enzyme can be isolated from rat liver (Weinstein *et al.*, *J. Biol. Chem.* **257**: 13845 (1982)); the human cDNA (Sasaki *et al.* (1993) *J. Biol. Chem.* **15 268**: 22782-22787; Kitagawa & Paulson (1994) *J. Biol. Chem.* **269**: 1394-1401) and genomic (Kitagawa *et al.* (1996) *J. Biol. Chem.* **271**: 931-938) DNA sequences are known, facilitating production of this enzyme by recombinant expression. In a preferred embodiment, the claimed sialylation methods use a rat ST3Gal III.

[0175] Other exemplary sialyltransferases of use in the present invention include those isolated from *Campylobacter jejuni*, including the  $\alpha$ (2,3). See, e.g., WO99/49051.

[0176] Sialyltransferases other those listed in Table 1, are also useful in an economic and efficient large-scale process for sialylation of commercially important glycopeptides. As a simple test to find out the utility of these other enzymes, various amounts of each enzyme

(1-100 mU/mg protein) are reacted with asialo- $\alpha_1$  AGP (at 1-10 mg/ml) to compare the ability of the sialyltransferase of interest to sialylate glycopeptides relative to either bovine ST6Gal I, ST3Gal III or both sialyltransferases. Alternatively, other glycopeptides or glycopeptides, or N-linked oligosaccharides enzymatically released from the peptide backbone can be used in place of asialo- $\alpha_1$  AGP for this evaluation. Sialyltransferases with the ability to sialylate N-linked oligosaccharides of glycopeptides more efficiently than ST6Gal I are useful in a practical large-scale process for peptide sialylation.

5 *d) GalNAc transferases*

[0177] N-acetylgalactosaminyltransferases are of use in practicing the present invention, particularly for binding a GalNAc moiety to an amino acid of the O-linked glycosylation site of the peptide. Suitable N-acetylgalactosaminyltransferases include, but are not limited to,  $\alpha$ (1,3) N-acetylgalactosaminyltransferase,  $\beta$ (1,4) N-acetylgalactosaminyltransferases (Nagata *et al.*, *J. Biol. Chem.* **267**: 12082-12089 (1992) and Smith *et al.*, *J. Biol. Chem.* **269**: 15162 (1994)) and polypeptide N-acetylgalactosaminyltransferase (Homa *et al.*, *J. Biol. Chem.* **268**: 15 12609 (1993)).

[0178] Production of proteins such as the enzyme GalNAc T<sub>I-XX</sub> from cloned genes by genetic engineering is well known. See, eg., U.S. Pat. No. 4,761,371. One method involves collection of sufficient samples, then the amino acid sequence of the enzyme is determined by N-terminal sequencing. This information is then used to isolate a cDNA clone encoding a full-length (membrane bound) transferase which upon expression in the insect cell line Sf9 resulted in the synthesis of a fully active enzyme. The acceptor specificity of the enzyme is then determined using a semiquantitative analysis of the amino acids surrounding known glycosylation sites in 16 different proteins followed by in vitro glycosylation studies of synthetic peptides. This work has demonstrated that certain amino acid residues are overrepresented in glycosylated peptide segments and that residues in specific positions surrounding glycosylated serine and threonine residues may have a more marked influence on acceptor efficiency than other amino acid moieties.

20 *Sulfotransferases*

[0179] The invention also provides methods for producing peptides that include sulfated molecules, including, for example sulfated polysaccharides such as heparin, heparan sulfate, carragenen, and related compounds. Suitable sulfotransferases include, for example,

chondroitin-6-sulphotransferase (chicken cDNA described by Fukuta *et al.*, *J. Biol. Chem.* **270**: 18575-18580 (1995); GenBank Accession No. D49915), glycosaminoglycan N-acetylglucosamine N-deacetylase/N-sulphotransferase 1 (Dixon *et al.*, *Genomics* **26**: 239-241 (1995); UL18918), and glycosaminoglycan N-acetylglucosamine N-deacetylase/N-  
5 sulphotransferase 2 (murine cDNA described in Orellana *et al.*, *J. Biol. Chem.* **269**: 2270-2276 (1994) and Eriksson *et al.*, *J. Biol. Chem.* **269**: 10438-10443 (1994); human cDNA described in GenBank Accession No. U2304).

#### *Cell-Bound Glycosyltransferases*

[0180] In another embodiment, the enzymes utilized in the method of the invention are  
10 cell-bound glycosyltransferases. Although many soluble glycosyltransferases are known (see, for example, U.S. Pat. No. 5,032,519), glycosyltransferases are generally in membrane-bound form when associated with cells. Many of the membrane-bound enzymes studied thus far are considered to be intrinsic proteins; that is, they are not released from the membranes by sonication and require detergents for solubilization. Surface glycosyltransferases have  
15 been identified on the surfaces of vertebrate and invertebrate cells, and it has also been recognized that these surface transferases maintain catalytic activity under physiological conditions. However, the more recognized function of cell surface glycosyltransferases is for intercellular recognition (Roth, *MOLECULAR APPROACHES to SUPRACELLULAR PHENOMENA*, 1990).

20 [0181] Methods have been developed to alter the glycosyltransferases expressed by cells. For example, Larsen *et al.*, *Proc. Natl. Acad. Sci. USA* **86**: 8227-8231 (1989), report a genetic approach to isolate cloned cDNA sequences that determine expression of cell surface oligosaccharide structures and their cognate glycosyltransferases. A cDNA library generated from mRNA isolated from a murine cell line known to express UDP-galactose:β-D-galactosyl-1,4-N-acetyl-D-glucosaminide α-1,3-galactosyltransferase was transfected into  
25 COS-1 cells. The transfected cells were then cultured and assayed for α 1-3 galactosyltransferase activity.

[0182] Francisco *et al.*, *Proc. Natl. Acad. Sci. USA* **89**: 2713-2717 (1992), disclose a method of anchoring β-lactamase to the external surface of *Escherichia coli*. A tripartite fusion consisting of (i) a signal sequence of an outer membrane protein, (ii) a membrane-spanning section of an outer membrane protein, and (iii) a complete mature β-lactamase sequence is produced resulting in an active surface bound β-lactamase molecule. However,  
30

the Francisco method is limited only to prokaryotic cell systems and as recognized by the authors, requires the complete tripartite fusion for proper functioning.

#### *Fusion Proteins*

[0183] In other exemplary embodiments, the methods of the invention utilize fusion proteins that have more than one enzymatic activity that is involved in synthesis of a desired glycopeptide conjugate. The fusion polypeptides can be composed of, for example, a catalytically active domain of a glycosyltransferase that is joined to a catalytically active domain of an accessory enzyme. The accessory enzyme catalytic domain can, for example, catalyze a step in the formation of a nucleotide sugar that is a donor for the glycosyltransferase, or catalyze a reaction involved in a glycosyltransferase cycle. For example, a polynucleotide that encodes a glycosyltransferase can be joined, in-frame, to a polynucleotide that encodes an enzyme involved in nucleotide sugar synthesis. The resulting fusion protein can then catalyze not only the synthesis of the nucleotide sugar, but also the transfer of the sugar moiety to the acceptor molecule. The fusion protein can be two or more cycle enzymes linked into one expressible nucleotide sequence. In other embodiments the fusion protein includes the catalytically active domains of two or more glycosyltransferases. See, for example, 5,641,668. The modified glycopeptides of the present invention can be readily designed and manufactured utilizing various suitable fusion proteins (see, for example, PCT Patent Application PCT/CA98/01180, which was published as WO 99/31224 on June 24, 1999.)

#### *Immobilized Enzymes*

[0184] In addition to cell-bound enzymes, the present invention also provides for the use of enzymes that are immobilized on a solid and/or soluble support. In an exemplary embodiment, there is provided a glycosyltransferase that is conjugated to a PEG via an intact glycosyl linker according to the methods of the invention. The PEG-linker-enzyme conjugate is optionally attached to solid support. The use of solid supported enzymes in the methods of the invention simplifies the work up of the reaction mixture and purification of the reaction product, and also enables the facile recovery of the enzyme. The glycosyltransferase conjugate is utilized in the methods of the invention. Other combinations of enzymes and supports will be apparent to those of skill in the art.

Purification of Peptide- and Other-Conjugates

[0185] The products produced by the above processes can be used without purification. However, it is usually preferred to recover the product. Standard, well-known techniques for recovery of glycosylated saccharides such as thin or thick layer chromatography, column chromatography, ion exchange chromatography, or membrane filtration can be used. It is preferred to use membrane filtration, more preferably utilizing a reverse osmotic membrane, or one or more column chromatographic techniques for the recovery as is discussed hereinafter and in the literature cited herein. For instance, membrane filtration wherein the membranes have molecular weight cutoff of about 3000 to about 10,000 can be used to remove proteins such as glycosyl transferases. Nanofiltration or reverse osmosis can then be used to remove salts and/or purify the product saccharides (see, e.g., WO 98/15581). Nanofilter membranes are a class of reverse osmosis membranes that pass monovalent salts but retain polyvalent salts and uncharged solutes larger than about 100 to about 2,000 Daltons, depending upon the membrane used. Thus, in a typical application, saccharides prepared by the methods of the present invention will be retained in the membrane and contaminating salts will pass through.

[0186] If the modified glycoprotein is produced intracellularly, as a first step, the particulate debris, either host cells or lysed fragments, is removed, for example, by centrifugation or ultrafiltration; optionally, the protein may be concentrated with a commercially available protein concentration filter, followed by separating the polypeptide variant from other impurities by one or more steps selected from immunoaffinity chromatography, ion-exchange column fractionation (e.g., on diethylaminoethyl (DEAE) or matrices containing carboxymethyl or sulfopropyl groups), chromatography on Blue-Sepharose, CM Blue-Sepharose, MONO-Q, MONO-S, lentil lectin-Sepharose, WGA-Sepharose, Con A-Sepharose, Ether Toyopearl, Butyl Toyopearl, Phenyl Toyopearl, SP-Sepharose, or protein A Sepharose, SDS-PAGE chromatography, silica chromatography, chromatofocusing, reverse phase HPLC (e.g., silica gel with appended aliphatic groups), gel filtration using, e.g., Sephadex molecular sieve or size-exclusion chromatography, chromatography on columns that selectively bind the polypeptide, and ethanol or ammonium sulfate precipitation.

[0187] Modified glycopeptides produced in culture are usually isolated by initial extraction from cells, enzymes, etc., followed by one or more concentration, salting-out, aqueous ion-exchange, or size-exclusion chromatography steps, e.g., SP Sepharose. Additionally, the

modified glycoprotein may be purified by affinity chromatography. HPLC may also be employed for one or more purification steps.

[0188] A protease inhibitor, *e.g.*, methylsulfonylfluoride (PMSF) may be included in any of the foregoing steps to inhibit proteolysis and antibiotics may be included to prevent the 5 growth of adventitious contaminants.

[0189] Within another embodiment, supernatants from systems which sproduce the modified glycopeptide of the invention are first concentrated using a commercially available protein concentration filter, for example, an Amicon or Millipore Pellicon ultrafiltration unit. Following the concentration step, the concentrate may be applied to a suitable purification 10 matrix. For example, a suitable affinity matrix may comprise a ligand for the peptide, a lectin or antibody molecule bound to a suitable support. Alternatively, an anion-exchange resin may be employed, for example, a matrix or substrate having pendant DEAE groups. Suitable matrices include acrylamide, agarose, dextran, cellulose, or other types commonly employed in protein purification. Alternatively, a cation-exchange step may be employed. Suitable 15 cation exchangers include various insoluble matrices comprising sulfopropyl or carboxymethyl groups. Sulfopropyl groups are particularly preferred.

[0190] Finally, one or more RP-HPLC steps employing hydrophobic RP-HPLC media, *e.g.*, silica gel having pendant methyl or other aliphatic groups, may be employed to further purify a polypeptide variant composition. Some or all of the foregoing purification steps, in various 20 combinations, can also be employed to provide a homogeneous modified glycoprotein.

[0191] The modified glycopeptide of the invention resulting from a large-scale fermentation may be purified by methods analogous to those disclosed by Urdal *et al.*, *J. Chromatog.* 296: 171 (1984). This reference describes two sequential, RP-HPLC steps for purification of recombinant human IL-2 on a preparative HPLC column. Alternatively, 25 techniques such as affinity chromatography may be utilized to purify the modified glycoprotein.

[0192] In another aspect, the invention provides a pharmaceutical composition. The pharmaceutical composition includes a pharmaceutically acceptable diluent and a covalent conjugate between a substrate (peptide, glycolipid, aglycone, etc.) and a modified sugar of 30 the invention.

[0193] An exemplary conjugate is formed between a non-naturally-occurring, water-soluble polymer, therapeutic moiety or biomolecule and a glycosylated or non-glycosylated

peptide. The polymer, therapeutic moiety or biomolecule is conjugated to the peptide via an intact glycosyl linking group interposed between and covalently linked to both the peptide and the polymer, therapeutic moiety or biomolecule.

[0194] Pharmaceutical compositions of the invention are suitable for use in a variety of 5 drug delivery systems. Suitable formulations for use in the present invention are found in *Remington's Pharmaceutical Sciences*, Mace Publishing Company, Philadelphia, PA, 17th ed. (1985). For a brief review of methods for drug delivery, *see*, Langer, *Science* 249:1527-1533 (1990).

[0195] The pharmaceutical compositions may be formulated for any appropriate manner of 10 administration, including for example, topical, oral, nasal, intravenous, intracranial, intraperitoneal, subcutaneous or intramuscular administration. For parenteral administration, such as subcutaneous injection, the carrier preferably comprises water, saline, alcohol, a fat, a wax or a buffer. For oral administration, any of the above carriers or a solid carrier, such as mannitol, lactose, starch, magnesium stearate, sodium saccharine, talcum, cellulose, glucose, 15 sucrose, and magnesium carbonate, may be employed. Biodegradable matrices, such as microspheres (*e.g.*, polylactate polyglycolate), may also be employed as carriers for the pharmaceutical compositions of this invention. Suitable biodegradable microspheres are disclosed, for example, in U.S. Patent Nos. 4,897,268 and 5,075,109.

[0196] Commonly, the pharmaceutical compositions are administered subcutaneously or 20 parenterally, *e.g.*, intravenously. Thus, the invention provides compositions for parenteral administration which comprise the compound dissolved or suspended in an acceptable carrier, preferably an aqueous carrier, *e.g.*, water, buffered water, saline, PBS and the like. The compositions may also contain detergents such as Tween 20 and Tween 80; stabilizers such as mannitol, sorbitol, sucrose, and trehalose; and preservatives such as EDTA and m-25 cresol. The compositions may contain pharmaceutically acceptable auxiliary substances as required to approximate physiological conditions, such as pH adjusting and buffering agents, tonicity adjusting agents, wetting agents, detergents and the like.

[0197] These compositions may be sterilized by conventional sterilization techniques, or 30 may be sterile filtered. The resulting aqueous solutions may be packaged for use as is, or lyophilized, the lyophilized preparation being combined with a sterile aqueous carrier prior to administration. The pH of the preparations typically will be between 3 and 11, more preferably from 5 to 9 and most preferably from 7 and 8.

[0198] In some embodiments the glycopeptides of the invention can be incorporated into liposomes formed from standard vesicle-forming lipids. A variety of methods are available for preparing liposomes, as described in, e.g., Szoka *et al.*, *Ann. Rev. Biophys. Bioeng.* 9: 467 (1980), U.S. Pat. Nos. 4,235,871, 4,501,728 and 4,837,028. The targeting of liposomes using 5 a variety of targeting agents (e.g., the sialyl galactosides of the invention) is well known in the art (see, e.g., U.S. Patent Nos. 4,957,773 and 4,603,044).

[0199] Standard methods for coupling targeting agents to liposomes can be used. These methods generally involve incorporation into liposomes of lipid components, such as phosphatidylethanolamine, which can be activated for attachment of targeting agents, or 10 derivatized lipophilic compounds, such as lipid-derivatized glycopeptides of the invention.

[0200] Targeting mechanisms generally require that the targeting agents be positioned on the surface of the liposome in such a manner that the target moieties are available for interaction with the target, for example, a cell surface receptor. The carbohydrates of the 15 invention may be attached to a lipid molecule before the liposome is formed using methods known to those of skill in the art (e.g., alkylation or acylation of a hydroxyl group present on the carbohydrate with a long chain alkyl halide or with a fatty acid, respectively).

Alternatively, the liposome may be fashioned in such a way that a connector portion is first incorporated into the membrane at the time of forming the membrane. The connector portion must have a lipophilic portion, which is firmly embedded and anchored in the membrane. It 20 must also have a reactive portion, which is chemically available on the aqueous surface of the liposome. The reactive portion is selected so that it will be chemically suitable to form a stable chemical bond with the targeting agent or carbohydrate, which is added later. In some cases it is possible to attach the target agent to the connector molecule directly, but in most instances it is more suitable to use a third molecule to act as a chemical bridge, thus linking 25 the connector molecule which is in the membrane with the target agent or carbohydrate which is extended, three dimensionally, off of the vesicle surface.

[0201] The compounds prepared by the methods of the invention may also find use as diagnostic reagents. For example, labeled compounds can be used to locate areas of 30 inflammation or tumor metastasis in a patient suspected of having an inflammation. For this use, the compounds can be labeled with  $^{125}\text{I}$ ,  $^{14}\text{C}$ , or tritium.

[0202] The following examples are provided to illustrate the conjugates, and methods and of the present invention, but not to limit the claimed invention.

## EXAMPLES

### Example 1

#### Preparation of UDP-GalNAc-6'-CHO

[0203] UDP-GalNAc (200 mg, 0.30 mmoles) was dissolved in a 1 mM CuSO<sub>4</sub> solution (20 mL) and a 25 mM NaH<sub>2</sub>PO<sub>4</sub> solution (pH 6.0; 20 mL). Galactose oxidase (240 U; 240  $\mu$ L) and catalase (13000 U; 130  $\mu$ L) were then added, the reaction system equipped with a balloon filled with oxygen and stirred at room temperature for seven days. The reaction mixture was then filtered (spin cartridge; MWCO 5K) and the filtrate (~40 mL) was stored at 4° C until required. TLC (silica; EtOH/water (7/2);  $R_f$  = 0.77; visualized with anisaldehyde stain).

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### Example 2

#### Preparation of UDP-GalNAc-6'-NH<sub>2</sub>):

[0204] Ammonium acetate (15 mg, 0.194 mmoles) and NaBH<sub>3</sub>CN (1M THF solution; 0.17 mL, 0.17 mmoles) were added to the UDP-GalNAc-6'-CHO solution from above (2 mL or ~ 20 mg) at 0°C and allowed to warm to room temperature overnight. The reaction was filtered through a G-10 column with water and the product collected. The appropriate fractions were freeze-dried and stored frozen. TLC (silica; ethanol/water (7/2);  $R_f$  = 0.72; visualized with ninhydrin reagent).

### Example 3

#### Preparation of UDP-GalNAc-6-NHCO(CH<sub>2</sub>)<sub>2</sub>-O-PEG-OMe (1 KDa).

[0205] The galactosaminyl-1-phosphate-2-NHCO(CH<sub>2</sub>)<sub>2</sub>-O-PEG-OMe (1 KDa) (58 mg, 0.045 mmoles) was dissolved in DMF (6 mL) and pyridine (1.2 mL). UMP-morpholidate (60 mg, 0.15 mmoles) was then added and the resulting mixture stirred at 70°C for 48 h. The solvent was removed by bubbling nitrogen through the reaction mixture and the residue purified by reversed phase chromatography (C-18 silica, step gradient between 10 to 80%, methanol/water). The desired fractions were collected and dried at reduced pressure to yield 50 mg (70%) of a white solid. TLC (silica, propanol/H<sub>2</sub>O/NH<sub>4</sub>OH, (30/20/2),  $R_f$  = 0.54). MS (MALDI): Observed, 1485, 1529, 1618, 1706.

[0206] While this invention has been disclosed with reference to specific embodiments, it is apparent that other embodiments and variations of this invention may be devised by others skilled in the art without departing from the true spirit and scope of the invention.

[0207] All patents, patent applications, and other publications cited in this application are  
5 incorporated by reference in the entirety.

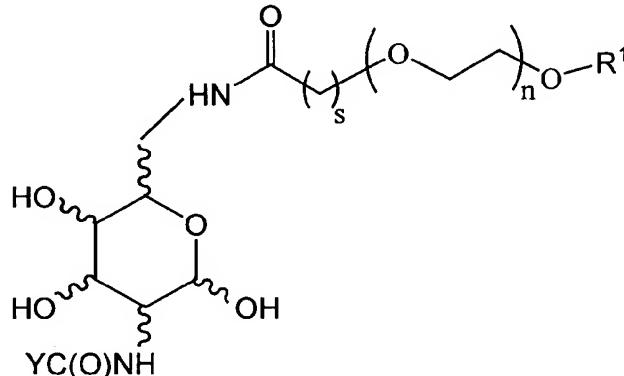
**WHAT IS CLAIMED IS:**

1           1.       A saccharide comprising a N-acyl moiety, and a member selected from  
2       a -XR-(CH<sub>2</sub>CH<sub>2</sub>O)<sub>n</sub>CH<sub>2</sub>CH<sub>2</sub>OR<sup>1</sup> and a -C(O)XR-(CH<sub>2</sub>CH<sub>2</sub>O)<sub>n</sub>CH<sub>2</sub>CH<sub>2</sub>OR<sup>1</sup> moiety at C-6,  
3       wherein  
4           R is a member selected from C(O)(CH<sub>2</sub>)<sub>s</sub>O, C(O)NH(CH<sub>2</sub>)<sub>s</sub>O, and C(O)O(CH<sub>2</sub>)<sub>s</sub>O;  
5           m is an integer from 0 to 20;  
6           R<sup>1</sup> is a member selected from H, and substituted or unsubstituted alkyl, and  
7           substituted or unsubstituted aryl;  
8           X is a member selected from O, S, NH, N;  
9           n is an integer from 1 to 2500; and  
10          s is an integer from 1 to 20.

11

1           2.       The saccharide according to claim 1 in which said N-acyl moiety is  
2       attached to C-2 of said saccharide.

1           3.       The saccharide according to claim 1 having the structure:



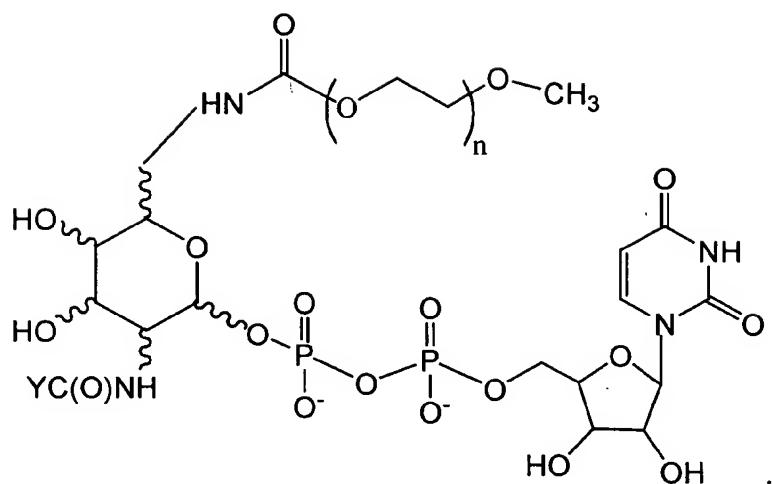
2       in which

3           Y is substituted or unsubstituted C<sub>1</sub>-C<sub>6</sub>alkyl.

1           4.       The saccharide according to claim 1 further comprising a nucleotide  
2       phosphate moiety.

1           5.       The saccharide according to claim 4, wherein said nucleotide  
2       phosphate is attached to C-1.

1           6.       The saccharide according to claim 4 having the structure:



2

### 3 in which

4 Y is substituted or unsubstituted C<sub>1</sub>-C<sub>6</sub> alkyl.

PATENT

Attorney Docket No.: 40853-01-5151PR

**Sugar Conjugates**

**ABSTRACT OF THE DISCLOSURE**

The present invention provides N-acetyl nucleotide sugar conjugates that are formed between a modifying group and an amine moiety on the sugar. Exemplary linking groups between the modifying group and the amine moiety include amides, ureas and urethanes.

I-SF/7127475.2

## Application Data Sheet

### Application Information

Application number::

Filing Date:: 07/29/04

Application Type:: Provisional

Subject Matter:: Utility

Suggested classification::

Suggested Group Art Unit::

CD-ROM or CD-R??::

Number of CD disks::

Number of copies of CDs::

Sequence Submission::

Computer Readable Form (CRF)?::

Number of copies of CRF::

Title::

Attorney Docket Number:: 40853-01-5151PR

Request for Early Publication:: No

Request for Non-Publication:: No

Suggested Drawing Figure::

Total Drawing Sheets::

Small Entity?:: Yes

Latin name::

Variety denomination name::

Petition included?:: No

Petition Type::

Licensed US Govt. Agency::

Contract or Grant Numbers One::

Secrecy Order in Parent Appl.?:: No

### **Applicant Information**

Applicant Authority Type:: Inventor  
Primary Citizenship Country:: US  
Status:: Full Capacity  
Given Name:: Shawn  
Middle Name::  
Family Name:: DeFrees  
Name Suffix::  
City of Residence:: North Wales  
State or Province of Residence:: PA  
Country of Residence:: US  
Street of Mailing Address:: 126 Filly Drive  
City of Mailing Address:: North Wales  
State or Province of mailing address:: PA  
Country of mailing address:: US  
Postal or Zip Code of mailing address:: 19454

### **Correspondence Information**

Correspondence Customer Number:: 043850

### **Representative Information**

Representative Customer Number:: 043850

### **Domestic Priority Information**

Application:: Continuity Type:: Parent Application:: Parent Filing Date::

### **Foreign Priority Information**

Country:: Application number:: Filing Date::

### **Assignee Information**

Assignee Name::

Street of mailing address::

City of mailing address::

State or Province of mailing address::

Country of mailing address::

Postal or Zip Code of mailing address::